

# **Acute Responses to High and Low Velocity Resistance Training in Patients with Chronic Heart Failure**

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in Partial Fulfillment of the Requirements  
for the Degree of Master of Science  
in the College of Kinesiology  
University of Saskatchewan  
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## **Abstract**

**Introduction and Purpose:** In chronic heart failure (CHF), exercise rehabilitation results in a reduced risk of mortality, decreased disease severity, and increased functional ability. Resistance training is an important component of cardiac rehabilitation; however, an optimal training velocity that produces physiological and functional benefits at minimal perceived exertion and cardiovascular stress has yet to be identified. CHF patients need to be very efficient and perform the exercise that will give them the greatest benefits because of their poor exercise tolerance and increased risk of cardiovascular complications during exercise. In older populations, high velocity resistance training results in greater improvements in functional ability than low velocity resistance training. The use of high velocity resistance training in patients with CHF has yet to be examined; however it may enhance higher velocity activities of daily living while using a lower training load. The lower load associated with high velocity training may be less strenuous and result in lower cardiovascular stress, whilst maintaining a relatively similar power output compared to traditional low-velocity training. The purpose of this study was to compare the acute cardiovascular responses and perceived exertion of high and low velocity resistance exercises.

**Methods and Measures:** 6 male and 1 female patients with systolic heart failure (CHF NYHA Class I-III) were recruited to perform two separate, randomly assigned exercise sessions. These sessions consisted of 5 exercises (hack squat, chest press, knee flexion, lat pull down and knee extension); one with a low velocity of contraction (3 second concentric phase: 3 second eccentric phase at 50% of the slow velocity 1-RM) and one with a high velocity (1 second concentric phase: 3 second eccentric phase at 50% of the high velocity 1-RM). During both sessions, heart rate, blood pressure, and a rating of perceived exertion (RPE) were obtained after the completion of each exercise.

**Results:** Despite a similar relative mechanical load, the high velocity workout produced significantly lower systolic blood pressure (121.2 vs. 132.8 mmHg), mean arterial pressure (87.8 vs. 93.5), and RPE (3.7 vs.4.8) than the low velocity workout ( $p<0.05$ ). The high velocity workout was not significantly different from the low velocity workout for heart rate, rate pressure product and diastolic blood pressure.

**Conclusion:** We conclude that the high velocity workout produces more favourable blood pressure responses to resistance training in patients with CHF than the low velocity workout and may be used to enhance functional outcomes in cardiac rehabilitation programs.

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## **Dedication**

I dedicate my master`s thesis to my parents. Thank you for all of your love, support, and encouragement throughout my entire student career. I would not be where I am today without your help and certainly this thesis would not exist.

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# **Chapter 1**

## **Scientific Framework**

### **1.1 Context**

There are approximately 400,000 Canadians living with chronic heart failure (CHF) and the number of cases are increasing<sup>1</sup>. More severe CHF (as typically determined by a worse New York Heart Association (NYHA) classification) is associated with an increased risk of death<sup>2</sup>. The NYHA classification system ranks the disease progression of Patients with CHF based on the severity of their symptoms. Exercise training is associated with an improvement in NYHA classification in Patients with CHF<sup>2</sup>. Specifically, resistance training is important for patients with CHF because it strengthens their weakened muscles without putting a load on their heart and thus limits their activity<sup>3</sup>. Optimal training programs that produce physiological and functional benefits at minimal perceived exertion and deleterious cardiac stress have yet to be identified. In healthy older adult populations, high velocity resistance training has been compared to low velocity resistance training and has been shown to result in greater improvements in muscle power and functional performance<sup>4,5</sup>. However, high and low velocity resistance training have yet to be compared in patients with CHF.

### **1.2 Objective**

The objective of this study was to compare the acute heart rate and blood pressure responses and perceived exertion during high and low velocity resistance exercises in patients with CHF.

## **1.3 Literature Review**

### **1.3.1 Chronic Heart Failure**

CHF is a complex syndrome in which abnormal heart function results in signs of low cardiac output and/or pulmonary or systemic congestion<sup>2</sup>. In simpler terms, the heart is unable to pump an adequate amount of oxygenated blood for the normal functions of the body. Patients with CHF can suffer from systolic dysfunction and/or diastolic dysfunction<sup>6</sup>. I will be focusing on patients with systolic dysfunction. In systolic dysfunction heart failure, damage to the heart results in a poor contractility of the ventricle, which leads to impaired blood flow<sup>6</sup>. It is characterized by a left ventricular ejection fraction (LVEF) of less than 35-40% and left ventricular dilation (diastolic diameter >5.6 cm at end-diastole) as assessed by echocardiography<sup>7</sup>.

The NYHA functional classification model is used to determine the cardiovascular event risk levels in patients with CHF based on the severity of their symptoms, such as undue fatigue, palpitations, dyspnoea, or angina at rest and during physical activity. Class I patients with CHF have no symptoms; class II have symptoms with ordinary activity; class III have symptoms with less than ordinary activity; and class IV have symptoms at rest or with any minimal activity<sup>2</sup>. Class I and II patients will only be recruited for this study because they are at a lower risk for cardiac complications. Examining heart rate and blood pressure responses to exercise can reflect the stress on the cardiovascular system and the degree of risk associated with the exercise being performed.

The reduction in oxygen delivery that occurs in patients with CHF decreases quality of life, exercise tolerance, and survival; CHF is associated with an annual mortality of 5% - 50%, depending on the severity of symptoms, heart dysfunction, and age<sup>2</sup>. These consequences of

CHF are due to both cardiac limitations and peripheral mal-adaptations of the skeletal musculature. The cardiac limitations include left ventricular impairment. The skeletal muscle mal-adaptations include: a reduction in the peripheral blood flow and impaired perfusion and deficiencies in skeletal muscle function, morphology, and metabolism<sup>8</sup>. The deterioration of skeletal musculature increases cardiovascular stress, increases symptoms, and further reduces exercise capacity<sup>8</sup>. Resistance training is a method used to maintain or increase skeletal muscle function and mass and can be extremely beneficial for patients with CHF to combat the aforementioned symptoms<sup>3</sup>.

Initial interventions for CHF recommended against exercise or any type of strenuous activity. The deleterious effects of both CHF and inactivity prompted research to be conducted on exercise training for patients with CHF. Endurance training was first investigated, followed by resistance training, and combined endurance and resistance training programs. Acute studies that demonstrated the safety of exercise training were followed by studies of exercise interventions that also confirmed the relative safety of exercise training.

### **1.3.2 The Safety of Resistance Training**

The safety of low velocity resistance training has been thoroughly investigated in patients with CHF. In a review by Meyer of 10 studies including 232 patients with CHF, the incidences of adverse events were low<sup>3</sup>. In only two studies was there an adverse event reported. Atrial fibrillation occurred in one study and a sudden death at home three days after the last training session occurred in the other study. This rate of adverse events is similar to those reported from training programs in CHF that did not include resistance exercises.

The acute physiological responses to resistance training are generally positive. During resistance training, left ventricular function is well maintained and the left ventricular response is

similar to that of endurance exercise<sup>9,10</sup>. Central hemodynamics, such as systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and cardiac output remain relatively stable throughout a resistance training session<sup>10</sup>. The hemodynamic burden is even lower during resistance exercise than in maximal and sub-maximal aerobic exercise<sup>11</sup>. The pattern of both hemodynamics and left ventricular responses to a set of a resistance exercise in patients with CHF is similar to that of young healthy adults<sup>12</sup>. Myocardial function remains stable with no left ventricular deterioration during upper and lower body exercise 1-RM testing, (i.e. evaluating strength by measuring the maximal amount of weight that can be lifted once using a specified movement pattern with a specified velocity) in patients with CHF making this type of testing acceptable<sup>12,13</sup>.

The positive findings of the acute studies allowed resistance exercise interventions to be studied to ensure that long term resistance exercise was also safe. Left ventricular function and structure, pro-inflammatory cytokines, cytokine receptors, and the N-terminal fragment of brain natriuretic peptide (NT-proBNP) have been studied to confirm the safety of resistance training. These measurements are explained below in more detail.

The measurements of left ventricle structure include left ventricular end diastolic diameter and left ventricle end systolic diameter. Ejection fraction, stroke volume and fractional shortening can be calculated from these measurements to assess left ventricular function.

Measurements of left ventricular function and structure are typically analyzed using echocardiography or radionuclide ventriculography. In systolic heart failure, the ventricles alter their size and geometry in response to chronic changes in hemodynamic load<sup>14</sup>. As a result the left ventricular end diastolic and end systolic diameters are increased in CHF because of retention of fluids caused by poor systolic function. A pathological increase in either diameter is

associated with a progression of the disease. Low velocity resistance training and combined resistance and endurance training either maintain<sup>15,16,17</sup> or decrease both diameters<sup>18,19,20</sup>. The maintenance is a positive outcome because in cases where a non-exercising control group was utilized, conditions worsened in the control group<sup>16</sup>. Resistance training improves or maintains measures of left ventricular function such as ejection fraction, stroke volume and fractional shortening<sup>15,21,16,19</sup>.

Higher levels of pro-inflammatory cytokines such as tumor necrosis factor (TNF- ) and interleukin-6 (IL-6) are present in patients with CHF<sup>22</sup>. These two cytokines are associated with left ventricular remodelling during the progression of the disease. TNF- induces the formation of oxygen free radicals which destroys nitric oxide produced in the endothelium<sup>22</sup>. The destruction of nitric oxide, a vasodilator, will lead to increased peripheral resistance causing an increase in stress on the heart by increasing blood pressure. Conraads et al. found that after a combined resistance and endurance training program cytokine levels remained the same and cytokine receptors, specifically soluble TNF- receptor-1, decreased<sup>22</sup>. The stability of the cytokine levels adds more support for the safety of resistance training. The decrease in TNF- receptor-1 suggests that the exercise training had an anti-inflammatory effect on both central and peripheral vasculature.

Brain natriuretic peptide (BNP) and NT-proBNP are secreted by ventricular cardiomyocytes (cardiac muscle cells) and reflect left ventricular diastolic wall stress<sup>23</sup>. They are also predictors of mortality and treatment success in CHF<sup>24,25</sup>. Four months of combined endurance and resistance training reduced NT-proBNP levels<sup>18</sup>. A decrease in left ventricular end systolic and diastolic diameters was also present which means that a lower diastolic wall stress could have caused the decrease in NT-proBNP secretion<sup>18</sup>. In summary, exercise training has a

beneficial effect on left ventricular remodelling and is safe for patients with CHF.

### 1.3.3 The Benefits of Resistance Training

There are numerous benefits for patients with CHF to participate in resistance training programs. Maintenance of most outcome measures is seen as positive because in most cases non-exercising control groups with CHF will deteriorate in function<sup>26,27,19</sup>. NYHA classification, functional status and quality of life improve with exercise training<sup>15,22,28</sup>. Changes in functional status are often assessed by improvements in 6-minute walk distance<sup>29,30</sup>. Changes in quality of life have most frequently been assessed by the Minnesota Living with Heart Failure Questionnaire<sup>32,19,17</sup>. Resistance training also improves peak oxygen consumption ( $\text{VO}_2$ ) (10-17%)<sup>26,32,19,27</sup>. In NYHA functional class II and III patients with CHF, peak  $\text{VO}_2$  is between 12 and 19  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  or 40-55% of age matched controls<sup>33</sup>. Improving peak  $\text{VO}_2$  is important because older people tend to lose their functional independence when  $\text{VO}_2$  falls below 15  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ <sup>34</sup>. These improvements can be traced back to other physiological characteristics that have benefited from resistance training, including improved muscular strength and endurance, sympathovagal balance, and central hemodynamics.

Significant improvements in muscular strength (15-43%) and muscular endurance (18-299%) occurred after resistance training<sup>29,35,30,21,26,32,19</sup>. These improvements have been attributed to morphological and histochemical changes in skeletal musculature. Morphological changes include an increased muscle fibre area and capillary per fibre ratio<sup>36</sup>. Feiereisen et al., found a 4% increase in thigh muscle volume after programs that included resistance training whereas the non-exercising control group encountered a decrease of 2%<sup>19</sup>. Increases in forearm blood flow have been attributed to the increased capillary density and an improvement in vascular function<sup>29,31,26</sup>. Maiorana et al. found improvements in forearm blood flow despite

focusing on avoiding any exercises that includes use of the forearms<sup>31</sup>. This suggests the beneficial effect of exercise on vascular function may be generalized and not specific to the vascular bed of the trained skeletal muscle. In the same study, endothelium- dependent vasodilation to acetylcholine and endothelium-independent vasodilation to sodium nitroprusside significantly increased which demonstrates the improvement in vascular function after resistance training<sup>31</sup>. This improvement is important because patients with CHF suffer from vascular dysfunction causing a reduced vasodilatory response<sup>37</sup>.

Histochemical improvements have contributed to the improvements in muscular endurance. After a 3-month resistance training program, Williams et al. found increases in several indices of muscle oxidative capacity<sup>27</sup>. A decrease was found in the non-exercising control group. The markers of oxidative capacity included mitochondrial ATP production rate and oxidative enzymes citrate synthase (a marker of the Krebs Cycle) and  $\alpha$ -hydroxyacyl coenzyme A dehydrogenase (a marker of fatty acid oxidation).

Heart rate variability has been used to study the sympatho-vagal balance in patients with CHF. Increased stimulation of the sympathetic nervous system and decreased activity of the parasympathetic nervous system occurs in patients with CHF, which causes an increase in resting HR, vasoconstriction in the peripheries and depressed heart rate variability<sup>38,39,40,41</sup>. A decreased heart rate variability is a strong and independent predictor of ventricular fibrillation and sudden cardiac death<sup>42</sup>. Resistance training improves the sympathovagal balance in patients with CHF and causes heart rate variability to increase<sup>26</sup>.

Resistance training, and combined resistance and endurance training programs are also beneficial for central hemodynamics. Resting HR, maximum HR, rate pressure product and stroke volume all change in response to exercise programs. Resting HR decreases because of the



decreased stimulation of the sympathetic nervous system<sup>15,18</sup>. Another symptom of CHF is chronotropic incompetence; which is defined as the inability of the heart to increase its rate in proportion to exercise and meet the metabolic demands of the body. In a clinical setting, chronotropic incompetence is defined as less than 80% of the age-predicted maximum HR in response to exercise in the presence of a respiratory exchange ratio of greater than 1.0 and a plateau in oxygen consumption<sup>43</sup>. An increase in maximal HR occurs with resistance training and is thought to be caused by the improvement in leg strength; which allows an increase in exercise time. By exercising for a longer period, it allows plasma norepinephrine levels to increase for a longer duration and to exert its chronotropic effect<sup>44,18</sup>. Rate pressure product (RPP) is the product of HR and SBP; it has been used as a marker for myocardial oxygen consumption which reflects how hard the heart has to work. RPP has a high correlation with myocardial oxygen consumption assessed with arterial catheterization ( $r = 0.88 - 0.90$ )<sup>45,46</sup>. Rate pressure product decreases suggesting a decrease in myocardial oxygen demand possibly caused by an increase in peripheral vasodilation and a decrease in afterload following exercise<sup>35</sup>. This suggests a decreased work stress on the heart.

### **1.3.4 Current Resistance Training Guidelines**

Research examining the optimal components of resistance training for patients with CHF is still ongoing. Different modes, intensities and loads have been studied for their safety and effectiveness. Meyer stated that resistance training is well tolerated when initial contraction intensity is low, small muscle groups are involved, work phases are kept short, a small number of repetitions per set is performed and a work to rest ratio is greater than 1:2<sup>3</sup>. Volaklis and Tomakidis suggested that intensity for NYHA Class I-II patients should start at 50-60% of 1-RM using machine weights and a perceived exertion rating should range from 'fairly light' to

'somewhat hard' on the Borg scale<sup>8</sup>. For duration, they recommend that work phases should not last longer than 60 seconds and an entire session should range from 20 to 30 minutes. The mode they suggest is bilateral whole body resistance training for NYHA class I patients and segmental unilateral training for NYHA II-III patients. Segmental unilateral training produces a lower hemodynamic response compared to bilateral whole body training allowing the higher class patients to not be overburdened during resistance exercise. Volaklis and Tomakidis recommend 4-6 seconds (2-3 for the concentric phase and 2-3 for the eccentric phase) for the tempo of the contraction<sup>8</sup>. This recommendation is solely based on previous studies that have only used that range of velocities. The impact of different velocities of contraction has been researched in only one acute study. Degache et al. found that HR and blood pressure responses were not different between 60°/s and 180°/s when performing 2 sets of 3 repetitions of knee extension and flexion<sup>47</sup>; however, the resistance training was performed on an isokinetic dynamometer which would elicit maximal contractions. There is a need to investigate the effect of high velocity resistance training where the power output is matched to slower velocity resistance training.

### **1.3.5 High Velocity Resistance Training**

High velocity resistance training focuses on the concentric phase of a resistance exercise being performed at a speed of one second or less. High velocity resistance training has been well studied in the older adult population and is associated with greater improvements in peak power, muscular power, and whole body physical function than low velocity training programs<sup>48,2,3</sup>. Muscle peak power, which is the target of high velocity training, is more closely related to the ability to perform activities of daily living than muscle strength, which is the target of traditional or low velocity training<sup>49</sup>. In most of the research studies performed on this subject, the training programs were not matched for power output or total workload per session. The participants in

the high velocity training programs typically performed lower total workloads than the low velocity participants. Despite the difference, both training programs similarly enhanced multiple components of muscle function and functional performance<sup>50,51</sup>. In CHF, this result can still be of value. A patient with CHF has a reduced exercise capacity at baseline and if they can receive the same benefit of a traditional low velocity workout from a high velocity workout at a lower work output, they may incur less cardiovascular stress and become less fatigued. There is a possibility that by matching power output, a high velocity workout may result in greater functional improvements, or that a high velocity workout at a lower workload may produce similar improvements but cause less cardiovascular strain and perceived effort.

### **1.3.6 Cardiovascular Responses to Resistance Training**

The cardiovascular responses in patients with CHF to resistance training have been examined sparingly and with varied resistance training protocols. The protocols differ in mode; i.e. isokinetic dynamometry<sup>47</sup> vs. isotonic<sup>52,10,11,12,13</sup> load, velocity of contraction, workload (number of sets and repetitions), exercise used (leg press, knee extension, knee flexion, biceps flexion, and shoulder press), and disease severity of the population studied (NYHA Classification). Cardiovascular responses to resistance training in the healthy population have been studied more thoroughly but the resistance training protocols are just as varied as the studies with patients with CHF. The results are consistent despite the differences in protocols being used.

In patients with CHF, HR significantly increases during a set of resistance exercise<sup>52,10</sup>. In healthy adults, the HR during one repetition of resistance exercise increases during the concentric portion of a lift and decreases slightly during the eccentric portion<sup>53</sup>. The magnitude of the HR response corresponds to the amount of effort required to lift a weight<sup>53</sup>. While lifting

an absolute weight a greater effort is required during the concentric phase than during the eccentric phase. A greater effort corresponds to a greater number of motor units required for the resistance exercise. The more motor units required, the more muscle mass being used, and a greater blood flow at the muscle is required<sup>54</sup>. During a set of resistance exercise, the highest HR is recorded during the concentric phase of the last repetition when the greatest numbers of motor units are recruited<sup>55,53</sup>. HR rises to increase the cardiac output to meet demands and to compensate for a decrease in stroke volume<sup>54</sup>. The decrease in stroke volume is due to an increase in total peripheral resistance throughout the set because of an increase in intramuscular pressure. The intramuscular pressure reduces venous return which reduces stroke volume<sup>54</sup>.

In patients with CHF, HR is greater during lower body vs. upper body exercises<sup>11</sup>, when more muscle mass is involved<sup>13</sup>, when a greater load (up to 100% of 1-RM) is used, and a greater number of repetitions and sets are performed<sup>47</sup>. These results can be explained by an increase in motor unit recruitment that requires a higher cardiac output. HR in patients with CHF is also influenced by their degree of left ventricular impairment. The greater the left ventricular impairment, the greater the HR response to a set of resistance exercise. In those with severe impairment, stroke volume decreases as exercise intensity increases and in order to meet demands HR increases to raise cardiac output<sup>11</sup>.

SBP, DBP, and mean arterial pressure (MAP) all significantly increase during resistance training in patients with CHF<sup>52,10</sup>. The mechanisms as to why this occurs have been more closely examined in healthy adults. Similar patterns occur between SBP, DBP and MAP as HR during one repetition and over the course of a set where highest blood pressures are seen during the concentric phase of the lift and the last repetition of the set. SBP is influenced by the number of sets performed, the rest interval, the load<sup>56,57,58,59</sup>, and the size of muscle mass<sup>60</sup>. The greater

number of sets performed, load, and muscle mass and the smaller the rest interval the greater the SBP response. The increase in SBP is related to the increase in HR that occurs<sup>61</sup>, the exercise pressor reflex<sup>61</sup>, and the mechanical compression of the arteries<sup>54, 62</sup>. SBP is a function of cardiac output multiplied by total peripheral resistance. Cardiac output is a function of HR and SV and typically when HR increases SBP will increase too. The exercise pressor reflex occurs during resistance exercise when more blood flow needs to be diverted to the contracting muscle. Vasoconstriction occurs in non-exercising tissues while arteries in the exercising muscle vasodilate to increase blood flow to the muscle<sup>61</sup>. The exercise pressor reflex is exaggerated in CHF patients causing increases in blood pressure, sympathetic nerve activity, and vascular resistance<sup>63</sup>. Fleck suggests that the exercise pressor reflex occurs when a set of resistance exercise is performed at 70-95% of 1-RM to failure<sup>64</sup>. The vasodilation that occurs at the muscle is opposed by the mechanical compression of the muscle, caused by the contracting muscle, which occurs when the exercise load is great enough<sup>61,54</sup>. Local blood flow becomes impeded at 40-60 % of maximal isometric contraction<sup>65, 66</sup>. The vasoconstriction from the exercise pressor reflex and the mechanical compression of the arteries at the exercising muscle causes an increase in total peripheral resistance which in turn increases SBP. DBP and MAP respond to resistance training the same as SBP<sup>10,61,53,54,60,67</sup>.

## **1.4 Hypothesis**

The hypothesis of this study is that high velocity resistance training will be more favourable regarding the acute cardiovascular responses and perceived exertion than low velocity training in patients with CHF. (1) The longer concentric contraction time in the low velocity session will cause an increase in blood pressures by occluding the blood vessels in the working muscle. (2) The higher blood pressures will require a higher HR to increase cardiac output to

match work level because venous return is decreased causing a reduced stroke volume. (3) The higher HR and blood pressures will cause a greater RPP response and also (4) make the low velocity session perceive to be more difficult than the high velocity session. The low velocity resistance training will produce significantly greater HR, SBP, DBP, MAP, rating of perceived exertion (RPE), and RPP than the high velocity resistance training.

## **Chapter 2**

### **Methods**

#### **2.1 Participants**

A sample of eight CHF patients were approached to participate in this research study. Seven NYHA Class I (n=4) and Class II (n=3), as determined by a cardiologist, systolic patients with CHF (6 males, 1 female) between 47 and 75 years of age were enrolled and participated in this study. All of them were enrolled in Cardiac Rehabilitation at the Saskatoon Field House at the time of participation. The study was approved by the University of Saskatchewan biomedical review board for research in human subjects, and all participants gave their written informed consent prior to data collection. (See Appendix A for a copy of the Ethics: Certificate of Approval). All testing and training was performed at the Saskatoon Field House Cardiac Rehabilitation Program. Their mean ( $\pm$ SD) age, height, body weight, Minnesota Living with Heart Failure Questionnaire (MLHFQ) Score and LVEF can be found in Table 2.1 All participants were on optimal medical treatment as determined by the primary cardiologist and were in a stable clinical condition for at least 6 weeks prior to inclusion (see Table 2.2 for a list of participant medications). Participants were excluded from participating if they were NYHA Class IV, had any malignant ventricular arrhythmias, advanced renal dysfunction (creatinine clearance <40), stroke, advanced chronic obstructive pulmonary disease ( $FEV_1 < 1.0$ ), or orthopedic limitations that would prevent them from performing the resistance exercises with proper form and no pain.

**Table 2.1 Participant Demographics**  
Data listed as Means  $\pm$  Standard Deviation

Age (years)	Weight (kg)	Height (cm)	BMI (kg/m <sup>2</sup> )	MLHFQ Score	LVEF (%)
63.3 $\pm$ 8.9	79.3 $\pm$ 9.2	168.4 $\pm$ 6.9	28.0 $\pm$ 3.0	42.4 $\pm$ 25.2	28.0 $\pm$ 9.2

MLHFQ = Minnesota Living with Heart Failure Quality of Life Questionnaire score

LVEF = Left ventricular ejection fraction

**Table 2.2 Participant Medications**

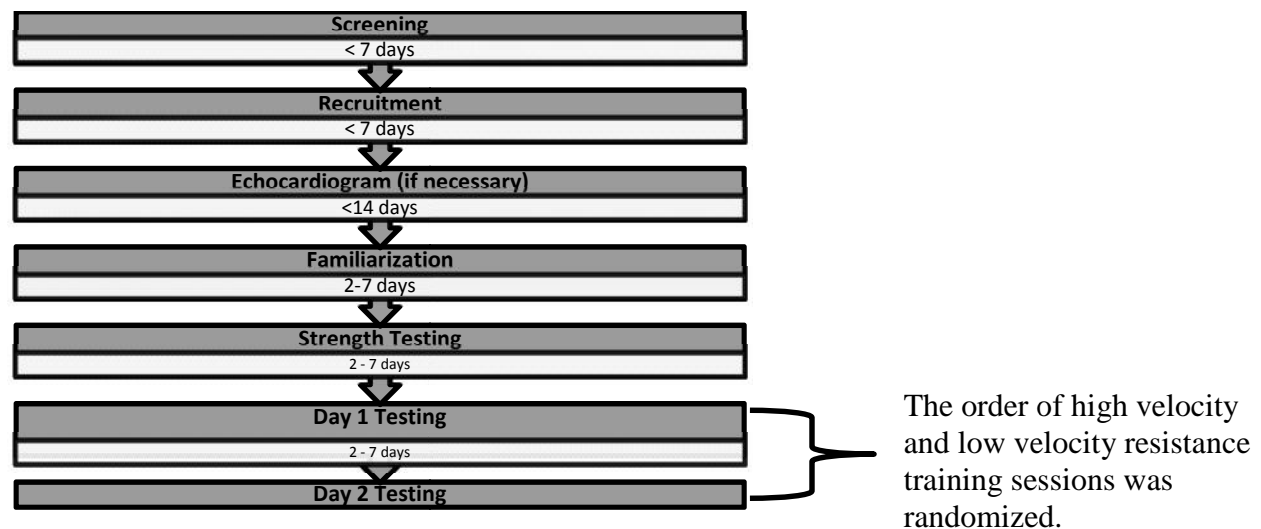
Drug Type	Participants on Drug	Number of Participants on Drug
& Adrenergic Blocking Agent	x, *, o, +	4
-blocker	$\diamond$ , $\square$ , $\Delta$	3
Aldosterone Receptor Blocker (Diuretic)	o, +	2
Angiotensin Converting Enzyme (ACE) Inhibitor	$\square$ , x, *, o	4
Angiotensin II Receptor Antagonist	$\diamond$	1
Antiarrhythmic Agent (Class III)	$\diamond$ , o	2
Anticoagulant (Blood Modifier)	$\diamond$ , $\Delta$ , x, *, o, +	6
Antiplatelet (Blood Modifier)	$\square$ , $\Delta$ , x, +	4
Calcium Channel Blocker	$\Delta$	1
Cardiac Glycoside	$\Delta$ , x, *, +	4
Cholesterol Absorption Inhibitor (Antilipemic Agent)	$\Delta$	1
HMG-CoA Reductase Inhibitor (Antilipemic Agent)	$\diamond$ , $\square$ , $\Delta$ , x, *, o	6
Loop Diuretic	$\square$ , $\Delta$ , *, o, +	5

## 2.2 Experimental Design

This research study was conducted using a within subject repeated measures design to assess two different conditions (high vs. low velocity resistance training). Participants performed one high velocity resistance training session and one low velocity resistance training session. The order in which they performed these sessions was randomized and counterbalanced between subjects.



**Figure 2.1 Study Design**



## 2.3 Training Session

Participants performed a 5-minute warm up before each resistance training session that involved walking or participating in a full body warm up class led by an exercise therapist at the Saskatoon Field House Cardiac Rehabilitation Program. Both resistance training sessions consisted of five weight machines that were performed in the following order: hack squat, chest press, knee extension, lat pull downs, and knee flexion. Participants were tested individually. The training session consisted of one set of 12 repetitions at 50% of their 1-RM for each exercise. This training session is similar to the start of the programs used by Conraads et al.<sup>18</sup>, Levinger et al.<sup>16</sup>, and Levinger et al.<sup>32</sup>. Rest followed the 1: 2 work-to-rest ratio recommended previously. The basis of this training program was intended to follow Meyer's recommendations<sup>3</sup>. To match for intensity, the 1-RM for the high velocity condition was based on a high velocity 1-RM strength test; whereas the 1-RM for the low velocity condition was based on a slow velocity test. Each of these tests will be explained below.

The low velocity resistance exercises were performed at a rate of 6 seconds per

repetition. The concentric phase lasted 3 seconds and the eccentric phase lasted 3 seconds (i.e. 3 seconds lifting the weight and 3 seconds lowering the weight). This velocity was based on what was used in the low velocity training group in the healthy older adult population<sup>5,51</sup> and what has also been used and recommended in patients with CHF<sup>21,19</sup>.

During the high velocity condition, participants performed their contractions at a rate of 4 seconds per repetition. The concentric phase lasted 1 second and the eccentric phase lasted 3 seconds. This velocity has been used in the older adult population in previous research<sup>4</sup>. The high velocity group's 1-RM was based on the greatest amount of weight lifted within 1 second. A metronome was used for the participants to control their tempo. After both sessions, participants were then instructed to perform a cool down that would involve a low-intensity aerobic exercise such as walking or using a stationary bicycle.

## **2.4 Measures**

Participants were screened upon their initial visit to ensure that they fit the inclusion criteria. After the screening process, participants were interviewed about their medical history and then had their height, weight, and blood pressure recorded. Participants filled out the quality of life questionnaire (see description below). Once these tests were completed, participants were then familiarized with the resistance training equipment. On the second day of testing, participants underwent an echocardiogram to assess cardiac function if they had not had one done in the previous 6 months. If the participant had an echocardiogram in the previous six months, they skipped this day of testing and the results of their previous echocardiogram were retrieved from the participant's medical record and used. The third day of testing consisted of strength testing for each exercise to determine the load for the testing days. There was at least 48 hours between each of the third, fourth, and fifth days. On the fourth and fifth days of testing,

using random assignment, participants performed either the high- or low-velocity protocol. During each session, heart rate, blood pressure and a rating of perceived exertion were recorded after every set of every exercise.

#### **2.4.1 Quality of Life**

Quality of life was assessed by the Minnesota Living with Heart Failure Questionnaire (MLHFQ). The MLHFQ assesses the effects of heart failure on an individual's quality of life. It consists of twenty-one items that focus on physical and emotional aspects to assess quality of life<sup>68</sup>. A CHF patient can score between 0 – 105 on it with a score of '0' inferring the highest quality of life and '105' the lowest quality of life. It has been found to be highly reliable in NYHA Class I & II ( $r = 0.87 - 0.93$ ,  $\alpha = 0.94 - 0.95$ )<sup>69</sup>. Mean MLHFQ scores were 21, 37, 53, and 69 in Class I, II, III, and IV patients, respectively<sup>69</sup>. The MLHFQ is commonly used in resistance training research studies for assessing quality of life<sup>32,19,17</sup>.

#### **2.4.2 Strength Testing**

1-RM testing on all exercises was used to determine the load for each exercise. High velocity 1-RM and regular 1-RM were assessed on all participants. The high velocity 1-RM was measured as the maximum amount of weight that was lifted with proper technique through a full range of motion in 1 second. The regular 1-RM was measured as the maximum amount of weight that can be lifted with proper technique through a full range of motion. The contraction tempo was maintained by a metronome. The strength testing protocol that was used was the one that was examined and confirmed to be safe by Werber-Zion et al<sup>13</sup>. Each evaluation started with a warm-up of 6-8 repetitions using a light weight. A weight of 2.5 – 10 kg was added for each repetition until they could not lift the weight following the aforementioned criteria. Each

repetition was separated by at least 2 minutes of rest. Similar protocols have been used in numerous resistance training studies in patients with CHF for strength testing<sup>32,19,17</sup>.

#### **2.4.4 Left Ventricular Ejection Fraction**

On those patients for whom echocardiography results were not obtained through a review of the medical record, LVEF was measured by using two-dimensional echocardiography using standardized methodology and commercially available equipment (Phillips IE33). The left ventricular end diastolic and end systolic diameters were measured from the parasternal long-axis view just below the level of the mitral valve. Anteroseptal and posterior systolic and diastolic wall thicknesses were also measured just below the level of the mitral valve. Ejection fraction was calculated from these measurements. Echocardiography has been used to measure LVEF in several prior CHF resistance training studies<sup>36,15,30,12,20</sup>.

#### **2.4.5 Cardiovascular Stress**

Cardiovascular stress was determined by measuring SBP, DBP, HR and electrocardiography. The blood pressures and HR were recorded after every set of exercise on day 4 and 5 of testing. The blood pressures were measured by arm auscultation in a similar manner as Werber-Zion et al<sup>13</sup>. The cuff was inflated near the end of the set and bled off throughout the last 2-3 repetitions because blood pressure measures return to baseline values within 5-10 seconds after a lift<sup>70</sup>. SBP represents the peak pressure that occurs in the arteries. It is the pressure that is exerted on the cardiovascular system when the heart contracts. DBP represents the lowest pressure that occurs. It is the pressure that is exerted on the cardiovascular system while the heart is relaxed. Mean arterial pressure (MAP) was calculated from SBP and DBP using the following formula:

$$MAP = DBP + \frac{(SBP - DBP)}{3}$$

MAP represents the average blood pressure that occurs. It is more heavily weighted on DBP because the heart spends more time in diastole than systole.

Rate pressure product (RPP), a measure of myocardial oxygen demand, was calculated using the following formula:

$$RPP = SBP \times HR$$

HR and electrocardiography were measured by a Phillips telemetry system utilizing a three lead hook up throughout the whole session.

#### **2.4.6 Rating of Perceived Exertion**

A rating of perceived exertion was attained after every set of exercise on days 4 and 5 of testing. A similar protocol was used by King et al. where a modified Borg scale was used after every set of resistance exercise<sup>71</sup>. The modified Borg scale ranges from '0' or a perceived exertion of 'nothing at all' to '10' or 'Maximum'. The participant performed a set of resistance training and then was asked, "How hard did you feel that you were working?" and was shown the modified Borg scale. Their answer was then recorded.

#### **2.5 Statistical Analysis**

Dependent *t*-tests were used to compare HR, SBP, diastolic blood pressure, mean arterial pressure, rate pressure product and RPE between the high velocity and low velocity exercise sessions. Data are expressed as means (SD) unless otherwise noted. An alpha level of 0.05 was considered statistically significant. Power was calculated using statistics software Statistica 6.0.

Demographics and quality of life measures were expressed through means and standard deviations.

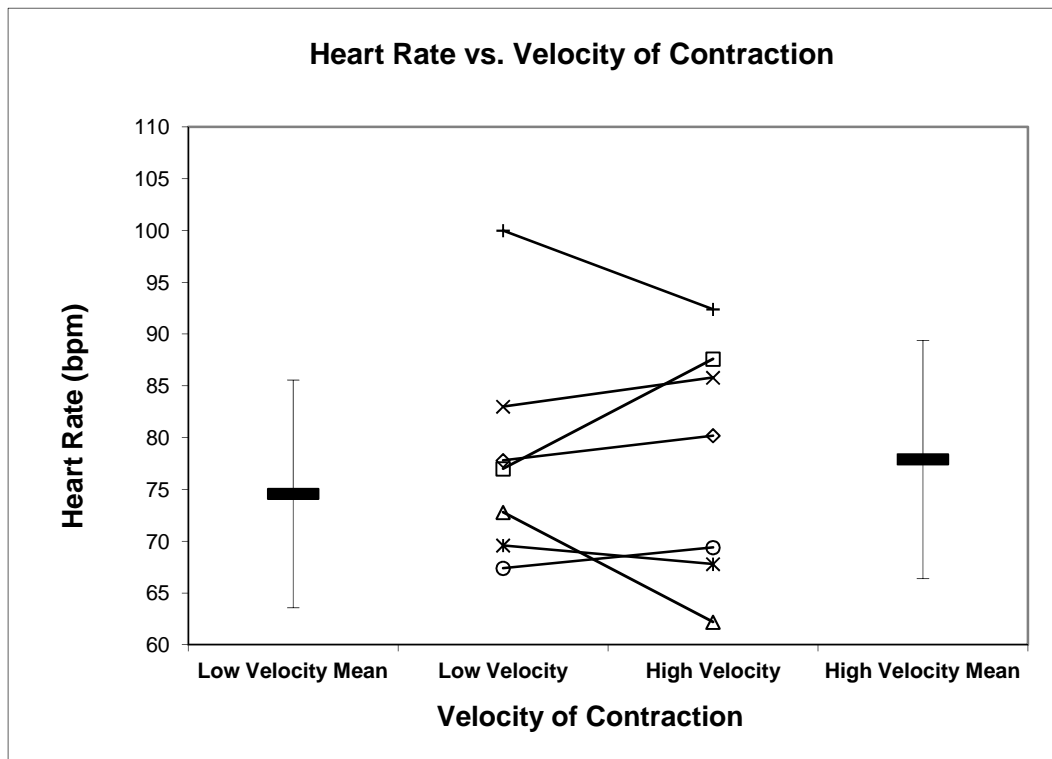
## Chapter 3

### Results

#### 3.1 Heart Rate

##### 3.1.1 Heart Rate vs. Velocity of Contraction for All Exercises

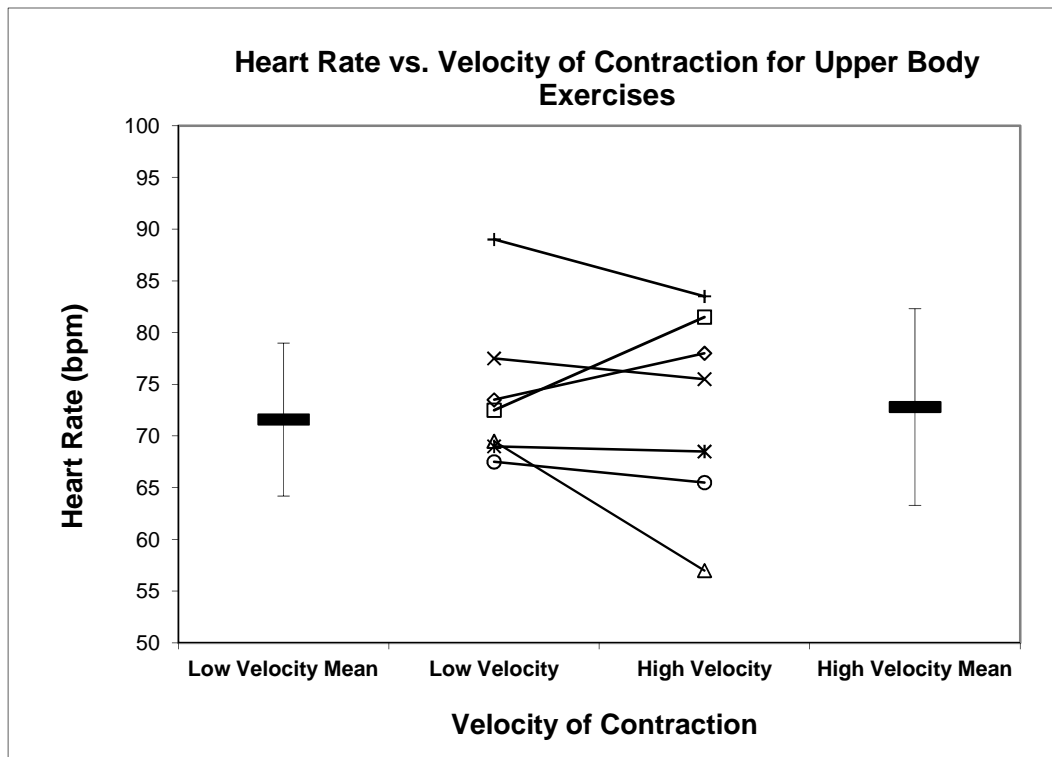
With the average of all 5 exercises combined the HR for the low velocity session was not significantly different from the high velocity session ( $p = 0.911$ ; power = 0.38; Figure 3.1.1).



**Figure 3.1.1 – Heart Rate vs. Velocity of Contraction.** Individual values and mean values are plotted. Values are in beats per minute. Error bars are standard deviations.

### 3.1.2 Heart Rate vs. Velocity of Contraction for the Upper Body Exercises

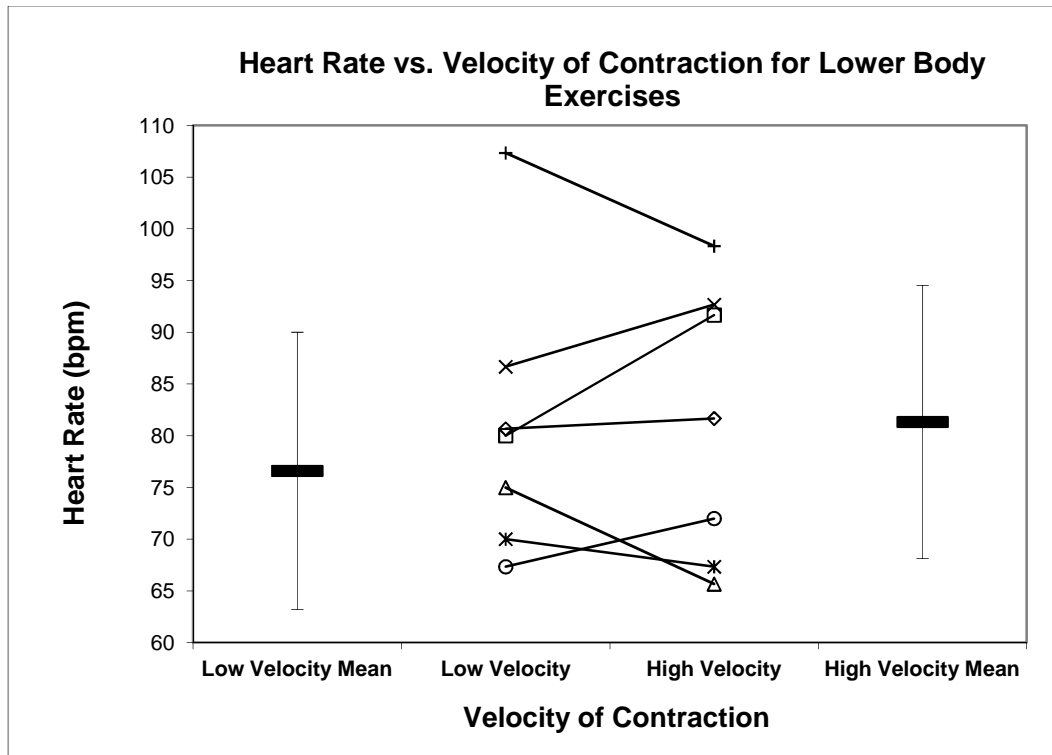
With the average of the upper body exercises combined, the HR for the low velocity session was not significantly different from the high velocity session ( $p = 0.639$ ; power = 0.08; Figure 3.1.2).



**Figure 3.1.2 – Heart Rate vs. Velocity of Contraction for the Upper Body Exercises.** Individual values and mean values are plotted. Values are in beats per minute. Error bars are standard deviations.

### 3.1.3 Heart Rate vs. Velocity of Contraction for the Lower Body Exercises

With the average of the lower body exercises combined, the HR for the low velocity session was not significantly different from the high velocity session ( $p = 0.914$ ; power = 0.40; Figure 3.1.3).



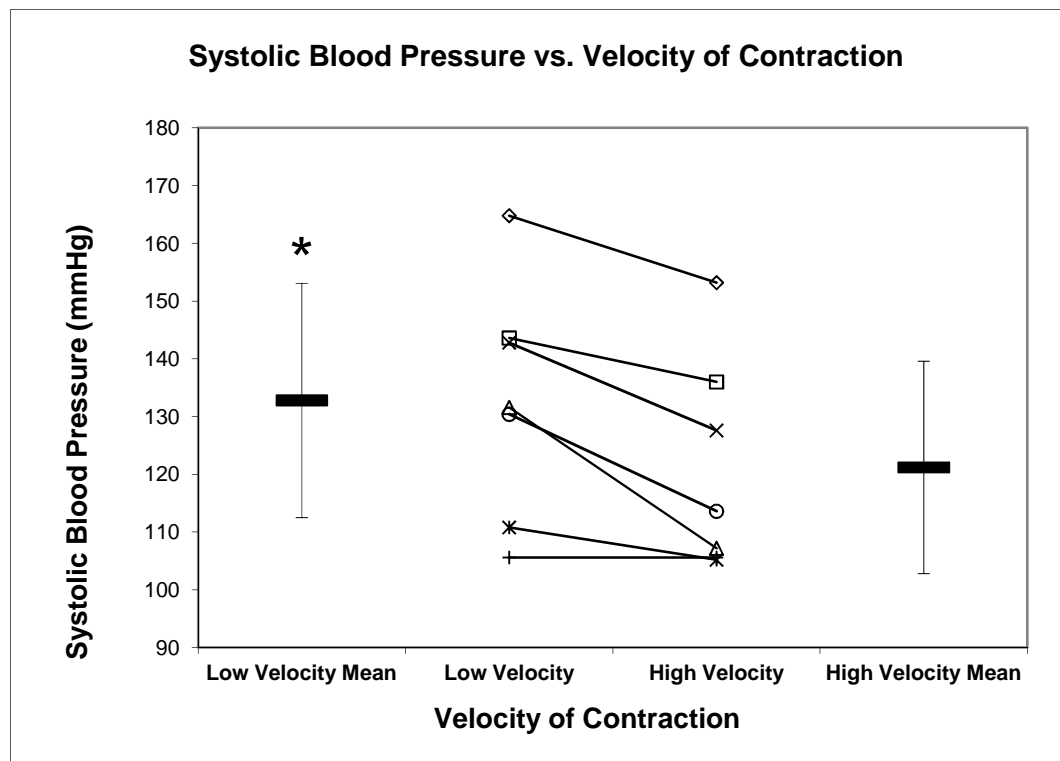
**Figure 3.1.3 – Heart Rate vs. Velocity of Contraction for the Lower Body Exercises.** Individual values and mean values are plotted. Values are in beats per minute. Error bars are standard deviations.



## 3.2 Systolic Blood Pressure

### 3.2.1 Systolic Blood Pressure vs. Velocity of Contraction for All Exercises

With the average of all 5 exercises combined the SBP for the low velocity session was significantly greater than the high velocity session ( $p < 0.01$ ; power = 0.81; Figure 3.2.1).



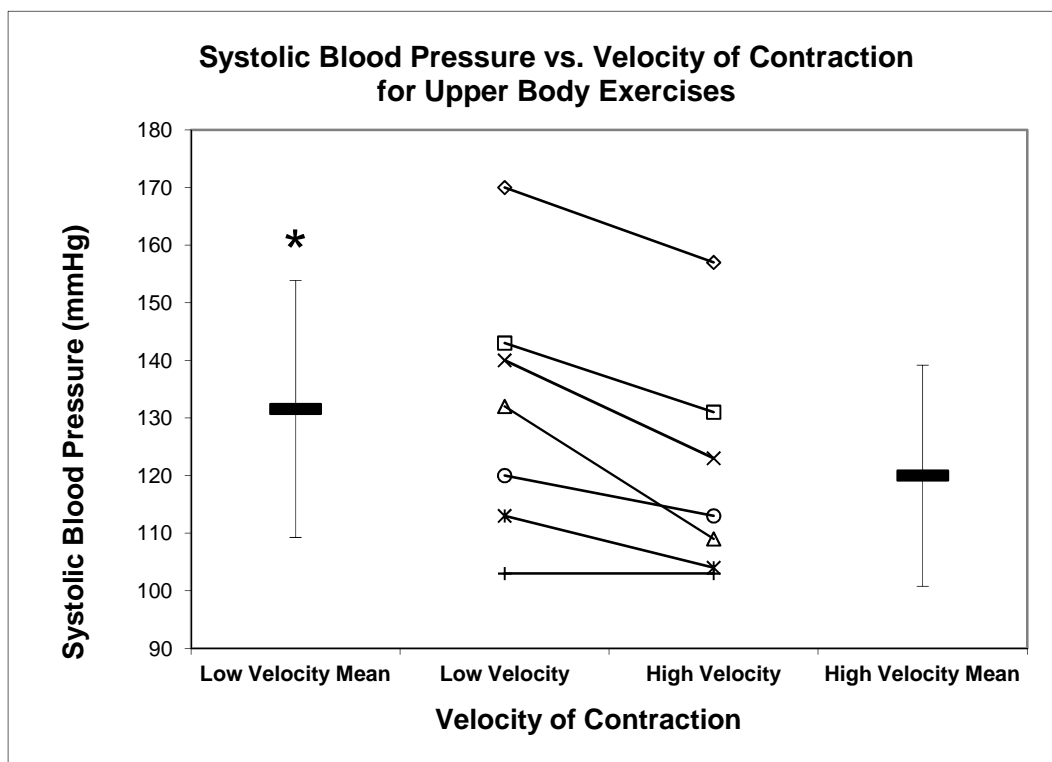
**Figure 3.2.1 – Systolic Blood Pressure vs. Velocity of Contraction.** Individual values and mean values are plotted. Values are in millimeters of mercury. Error bars are standard deviations.

\*SBP for the low velocity session is significantly greater than for the high velocity session ( $p < 0.01$ ).

### 3.2.2 Systolic Blood Pressure vs. Velocity of Contraction for the Upper Body

#### Exercises

With the average of the upper body exercises combined, the SBP for the low velocity session was significantly greater than the high velocity session ( $p < 0.01$ ; power = 0.76; Figure 3.2.2).



**Figure 3.2.2 – Systolic Blood Pressure vs. Velocity of Contraction for the Upper**

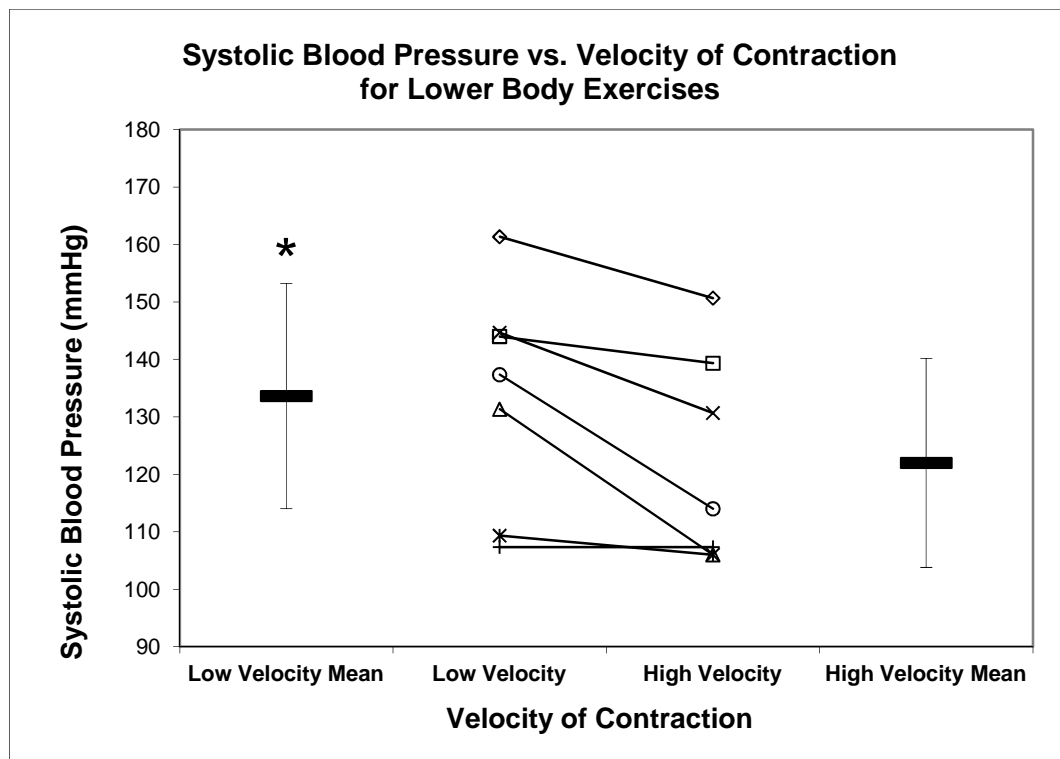
**Body Exercises.** Individual values and mean values are plotted. Values are in millimeters of mercury. Error bars are standard deviations.

\*SBP for the low velocity session is significantly greater than for the high velocity session ( $p < 0.01$ ).

### 3.2.3 Systolic Blood Pressure vs. Velocity of Contraction for the Lower Body

#### Exercises

With the average of the lower body exercises combined, the SBP for the low velocity session was significantly greater than the high velocity session ( $p < 0.05$ ; power = 0.90; Figure 3.2.2).



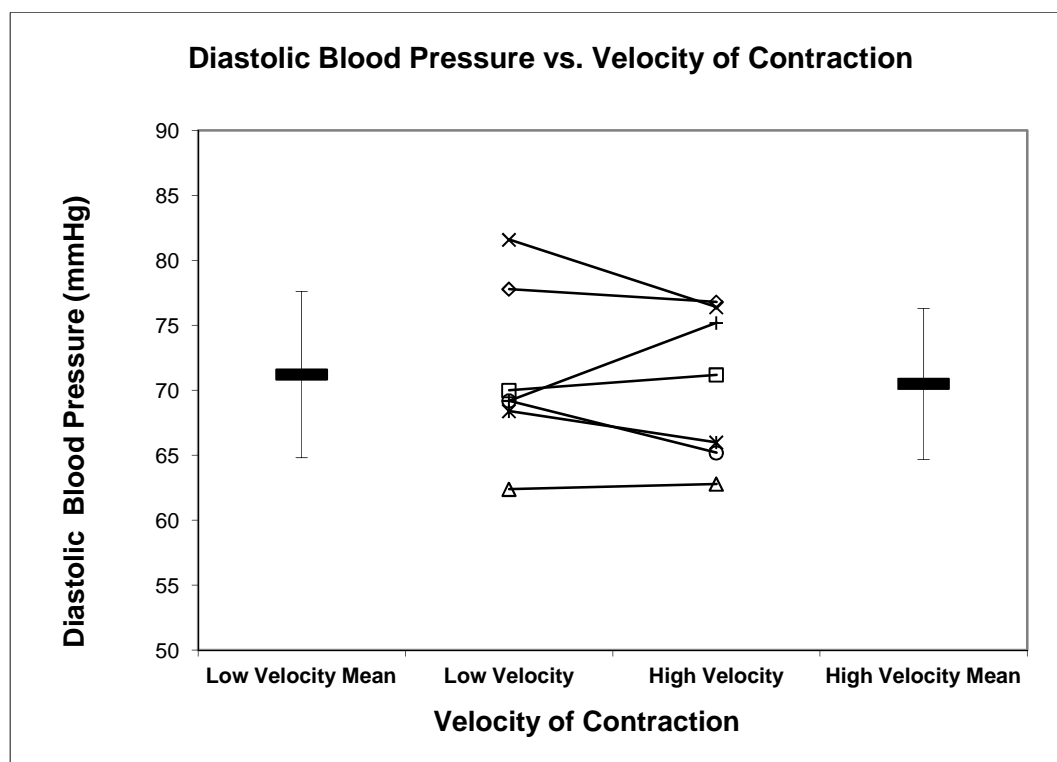
**Figure 3.2.3 – Systolic Blood Pressure vs. Velocity of Contraction for the Lower Body Exercises.** Individual values and mean values are plotted. Values are in millimeters of mercury. Error bars are standard deviations.

\*SBP for the low velocity session is significantly greater than for the high velocity session ( $p < 0.05$ ).

### 3.3 Diastolic Blood Pressure

#### 3.3.1 Diastolic Blood Pressure vs. Velocity of Contraction for All Exercises

With the average of all 5 exercises combined the diastolic blood pressure for the low velocity session was not significantly different from the high velocity session ( $p = 0.631$ ; power = 0.09; Figure 3.3.1).

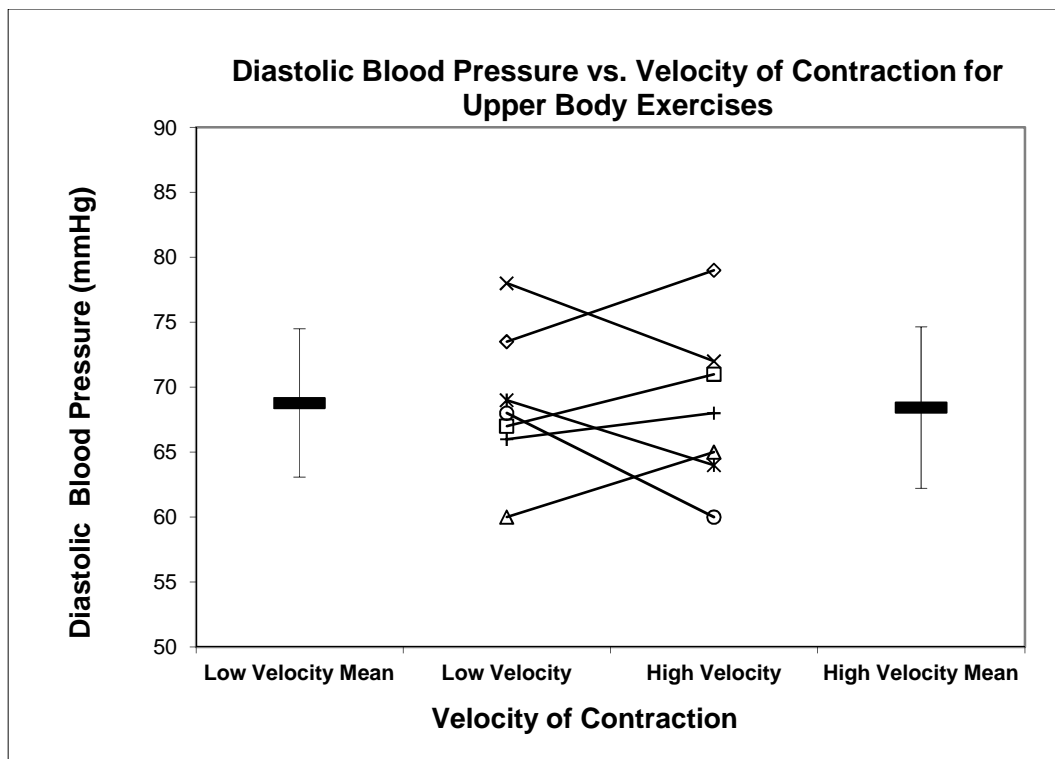


**Figure 3.3.1 – Diastolic Blood Pressure vs. Velocity of Contraction.** Individual values and mean values are plotted. Values are in millimeters of mercury. Error bars are standard deviations.

### 3.3.2 Diastolic Blood Pressure vs. Velocity of Contraction for the Upper Body

#### Exercises

With the average of the upper body exercises combined, the diastolic blood pressure for the low velocity session was not significantly different from the high velocity session ( $p = 0.875$ ; power = 0.06; Figure 3.3.2).

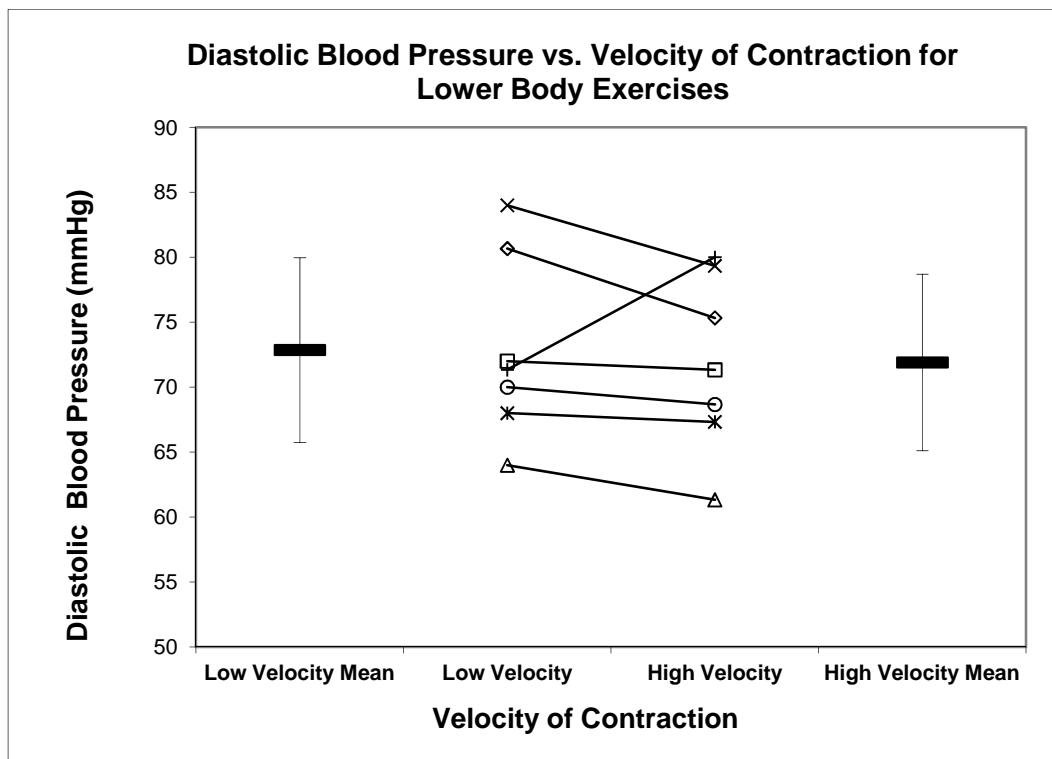


**Figure 3.3.2 – Diastolic Blood Pressure vs. Velocity of Contraction for the Upper Body Exercises.** Values are in millimeters of mercury. Individual values and mean values are plotted. Error bars are standard deviations.

### 3.3.3 Diastolic Blood Pressure vs. Velocity of Contraction for the Lower Body

#### Exercises

With the average of the lower body exercises combined, the diastolic blood pressure for the low velocity session was not significantly different from the high velocity session ( $p = 0.606$ ; power = 0.11; Figure 3.3.3).

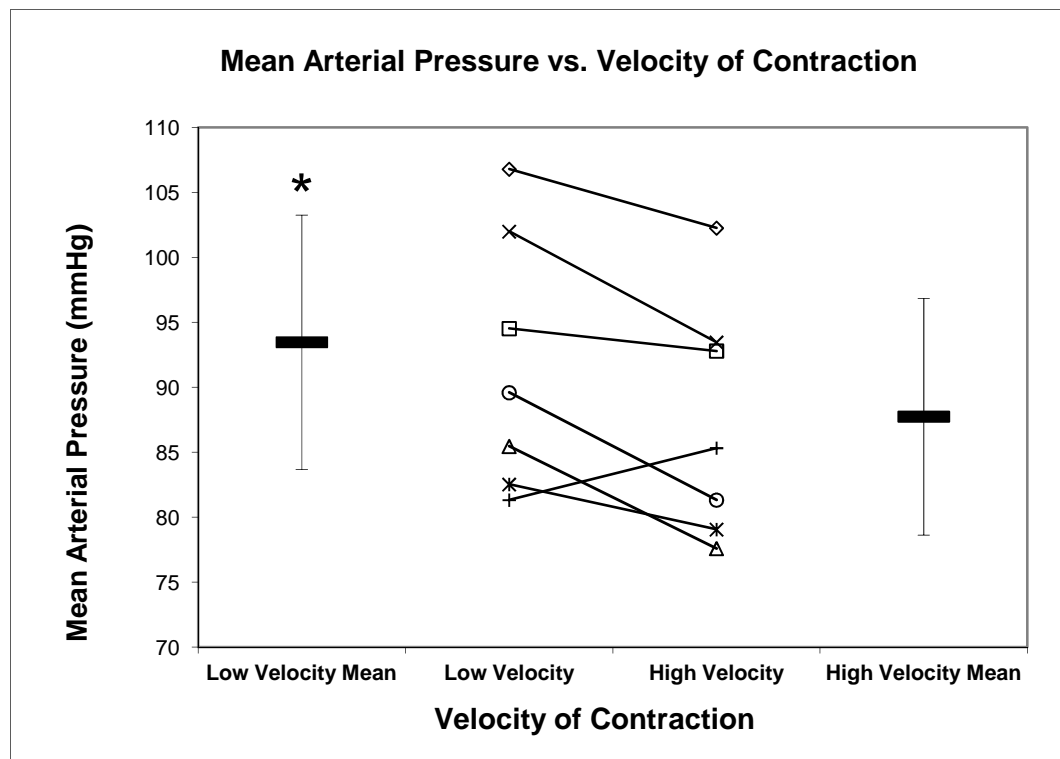


**Figure 3.3.3 – Diastolic Blood Pressure vs. Velocity of Contraction for the Lower Body Exercises.** Individual values and mean values are plotted. Values are in millimeters of mercury. Error bars are standard deviations.

### 3.4 Mean Arterial Pressure

#### 3.4.1 Mean Arterial Pressure vs. Velocity of Contraction for All Exercises

With the average of all 5 exercises combined the mean arterial pressure for the low velocity session was significantly greater than the high velocity session ( $p < 0.05$ ; power = 0.80; Figure 3.4.1).



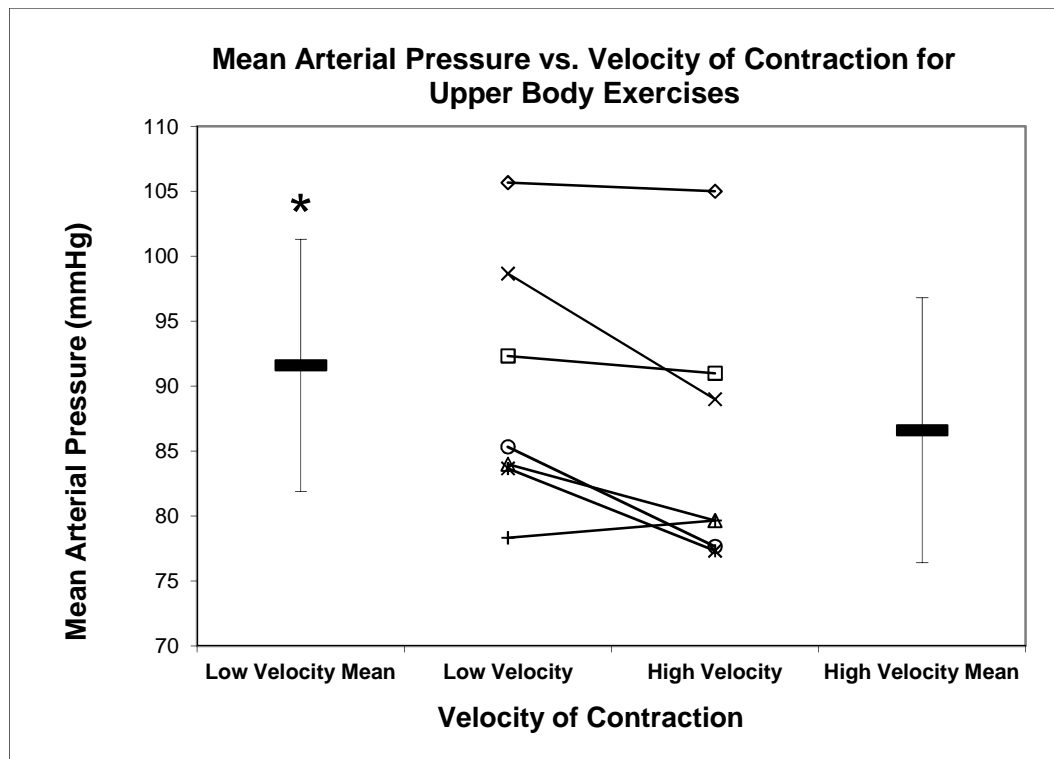
**Figure 3.4.1 – Mean Arterial Pressure vs. Velocity of Contraction.** Values are in millimeters of mercury. Individual values and mean values are plotted. Error bars are standard deviations.

\*Mean arterial pressure for the low velocity session is significantly greater than for the high velocity session ( $p < 0.05$ ).

### 3.4.2 Mean Arterial Pressure vs. Velocity of Contraction for the Upper Body

#### Exercises

With the average of all upper body exercises combined, the mean arterial pressure for the low velocity session was significantly greater than the high velocity session ( $p < 0.05$ ; power = 0.69; Figure 3.4.2).



**Figure 3.4.2 – Mean Arterial Pressure vs. Velocity of Contraction for the Upper Body Exercises.** Individual values and mean values are plotted. Values are in millimeters of mercury. Error bars are standard deviations.

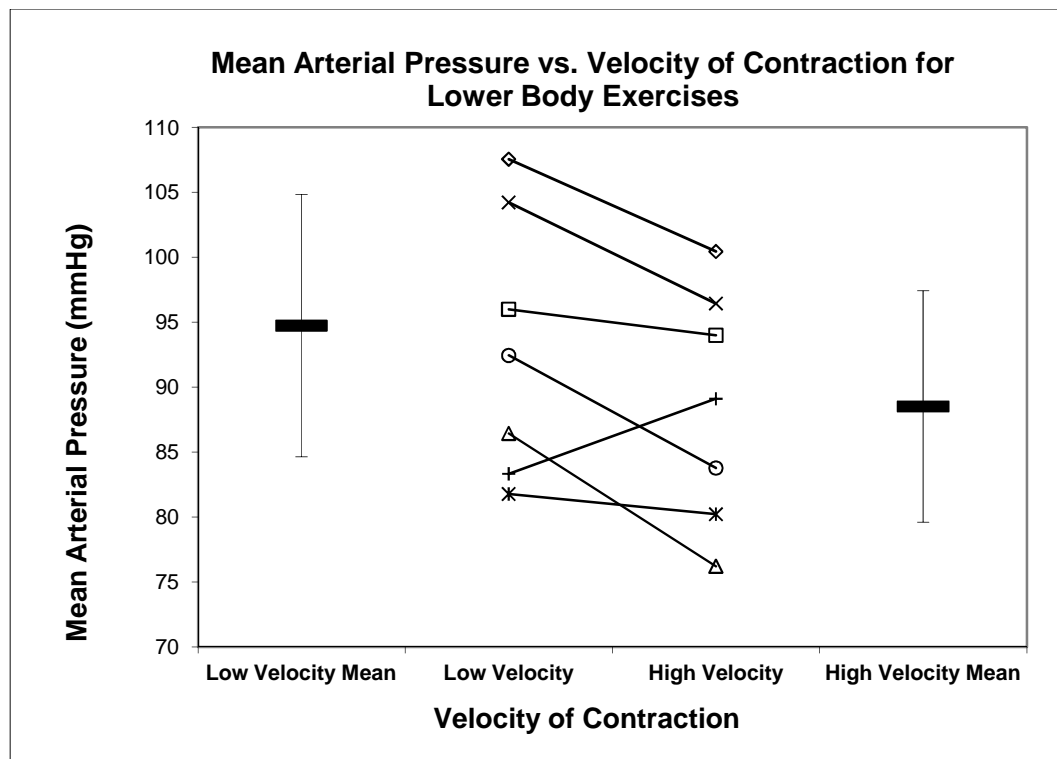
\*SBP for the low velocity session is significantly greater than for the high velocity session ( $p < 0.05$ ).



### 3.4.3 Mean Arterial Pressure vs. Velocity of Contraction for the Lower Body

#### Exercises

With the average of all lower body exercises combined, the mean arterial pressure for the low velocity session was not significantly different from the high velocity session ( $p = 0.077$ ; power = 0.86; Figure 3.4.3).

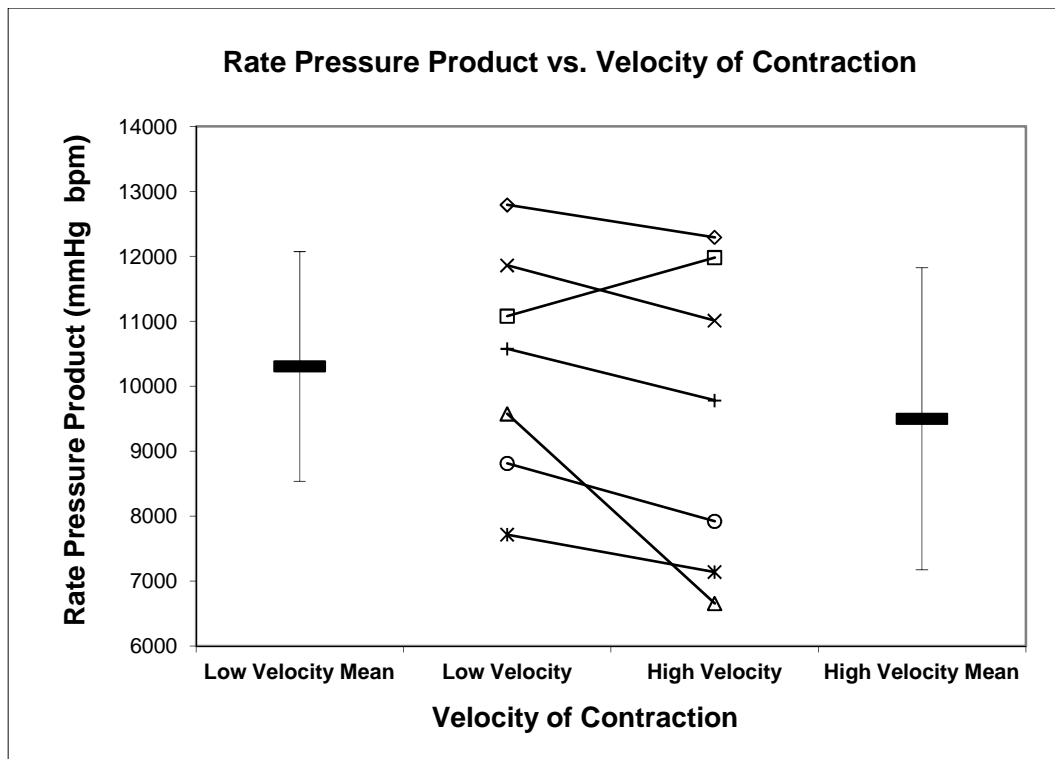


**Figure 3.4.3 – Mean Arterial Pressure vs. Velocity of Contraction for the Lower Body Exercises.** Individual values and mean values are plotted. Values are in millimeters of mercury. Error bars are standard deviations.

### 3.5 Rate Pressure Product

#### 3.5.1 Rate Pressure Product vs. Velocity of Contraction for All Exercises

With the average of all 5 exercises combined the rate pressure product for the low velocity session was not significantly different from the high velocity session ( $p = 0.106$ ; power = 0.38; Figure 3.5.1).

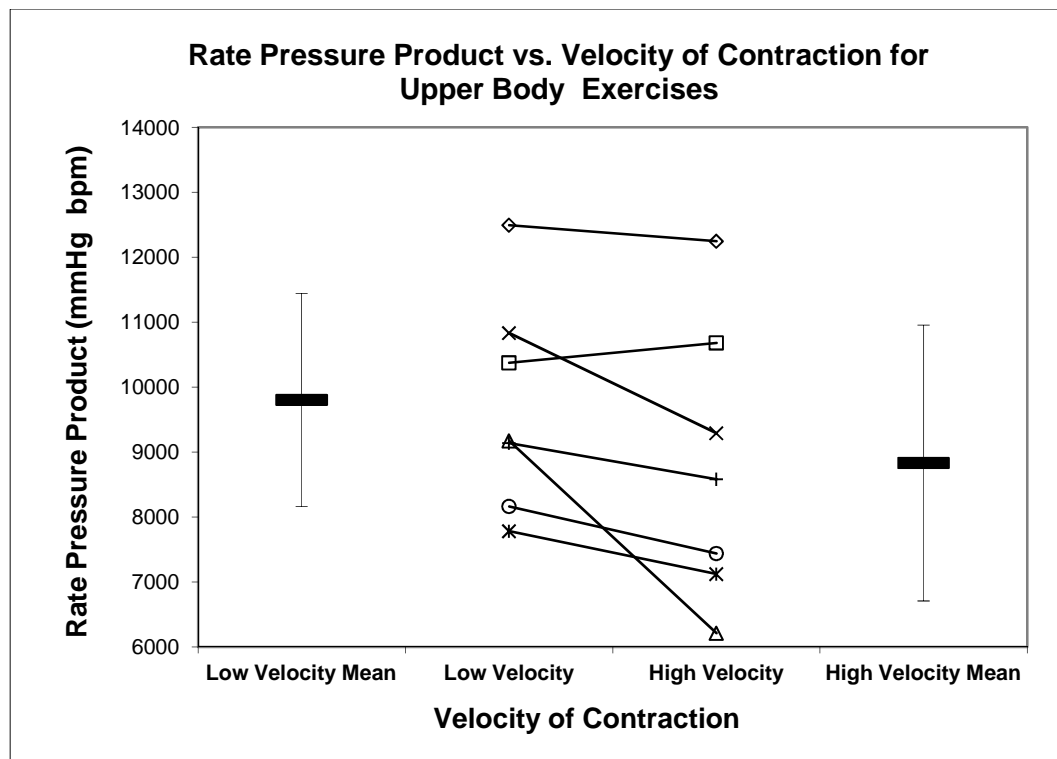


**Figure 3.5.1 – Rate Pressure Product vs. Velocity of Contraction.** Individual values and mean values are plotted. Error bars are standard deviations.

### 3.5.2 Rate Pressure Product vs. Velocity of Contraction for the Upper Body

#### Exercises

With the average of the upper body exercises combined the rate pressure product for the low velocity session was not significantly different from the high velocity session ( $p = 0.063$ ; power = 0.69; Figure 3.5.2).

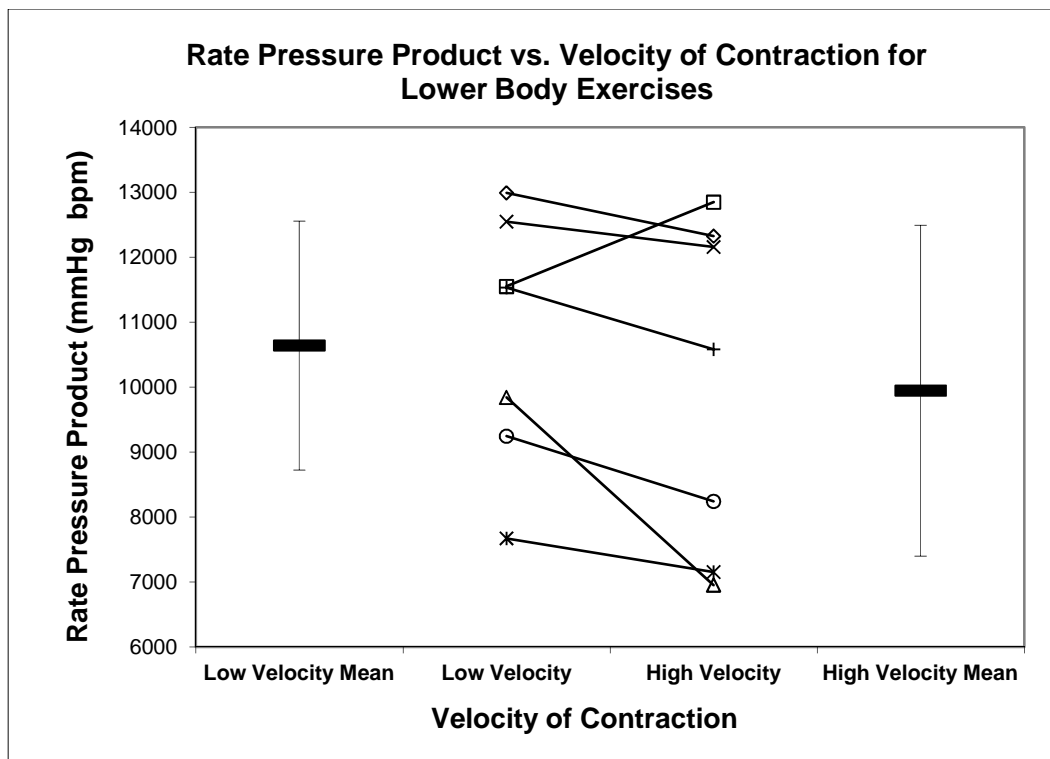


**Figure 3.5.2 – Rate Pressure Product vs. Velocity of Contraction for the Upper Body Exercises.** Individual values and mean values are plotted. Error bars are standard deviations.

### 3.5.3 Rate Pressure Product vs. Velocity of Contraction for the Lower Body

#### Exercises

With the average of the lower body exercises combined the rate pressure product for the low velocity session was not significantly different from the high velocity session ( $p = 0.166$ ; power = 0.29; Figure 3.5.3).

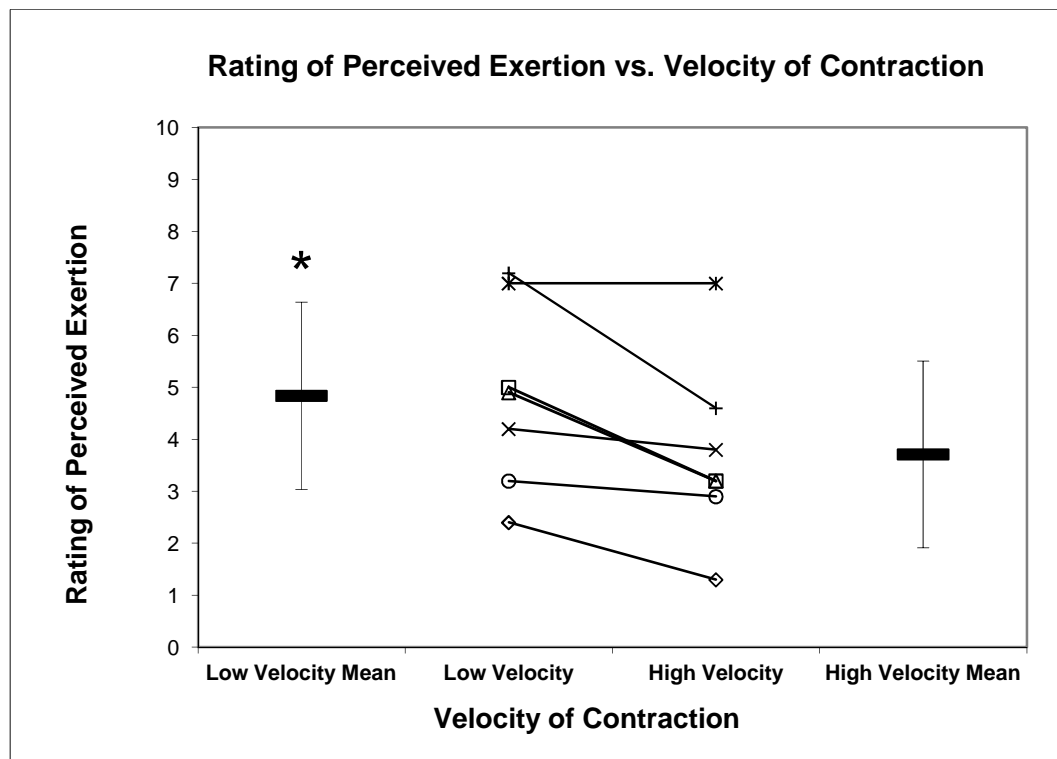


**Figure 3.5.3 – Rate Pressure Product vs. Velocity of Contraction for the Lower Body Exercises.** Individual values and mean values are plotted. Error bars are standard deviations.

### 3.6 Rating of Perceived Exertion

#### 3.6.1 Rating of Perceived Exertion vs. Velocity of Contraction for All Exercises

With the average of all 5 exercises combined the rating of perceived exertion for the low velocity session was significantly greater than the high velocity session ( $p < 0.05$ ; power = 0.86; Figure 3.6.1).



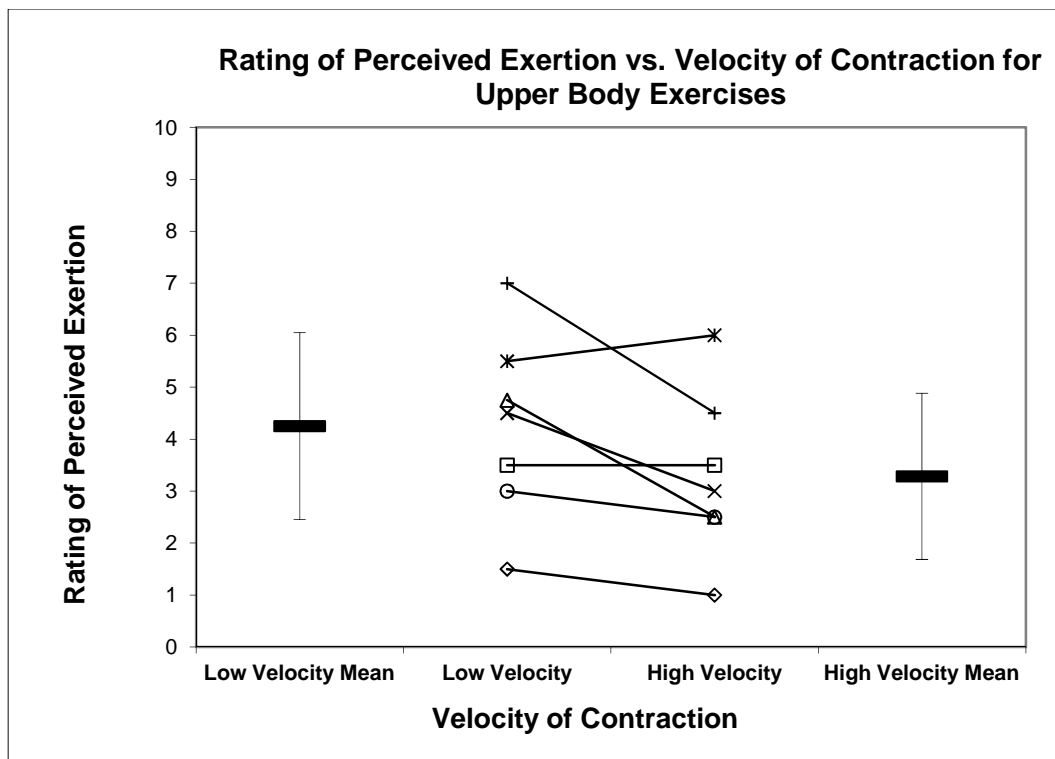
**Figure 3.6.1 – Rating of Perceived Exertion vs. Velocity of Contraction.** Individual values and mean values are plotted. Error bars are standard deviations.

\*Rating of perceived exertion for the low velocity session is significantly greater than for the high velocity session ( $p < 0.05$ ).

### 3.6.2 Rating of Perceived Exertion vs. Velocity of Contraction for the Upper Body

#### Exercises

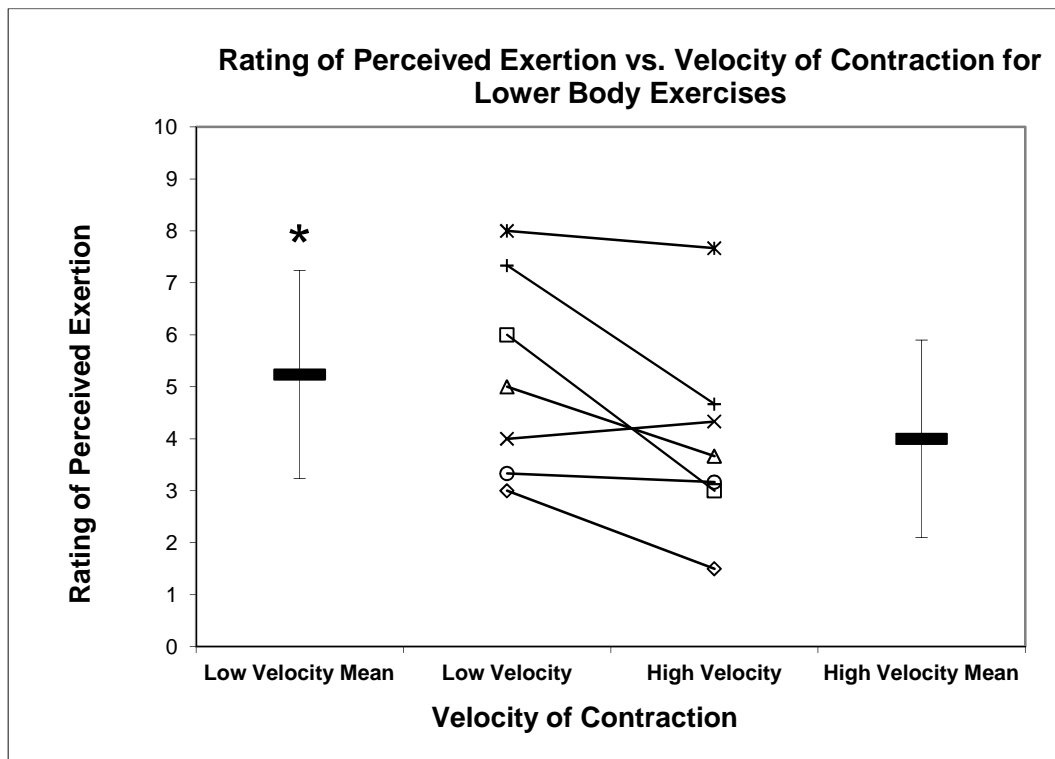
With average of the upper body exercises combined, the rating of perceived exertion for the low velocity session was not significantly different from the high velocity session ( $p = 0.067$ ; power = 0.72; Figure 3.6.2).



**Figure 3.6.2 – Rating of Perceived Exertion vs. Velocity of Contraction for the Upper Body Exercises.** Individual values and mean values are plotted. Error bars are standard deviations.

### 3.6.3 Rating of Perceived Exertion vs. Velocity of Contraction for the Lower Body Exercises

With the average of lower body exercises combined, the rating of perceived exertion for the low velocity session was significantly greater than the high velocity session ( $p < 0.05$ ; power = 0.86; Figure 3.6.3).



**Figure 3.6.3 – Rating of Perceived Exertion vs. Velocity of Contraction for the Lower Body Exercises.** Individual values and mean values are plotted. Error bars are standard deviations.

\*Rating of perceived exertion for the low velocity session is significantly greater than for the high velocity session ( $p < 0.05$ ).

### 3.7 Mean 1-Repetition Maximum Values

#### 3.7.1 High Velocity 1-Repetition Maximum Values

Data listed as Means  $\pm$  Standard Deviation

All values are in kilograms.

Hack Squat	61.7 $\pm$ 27.0
Bench Press	30.5 $\pm$ 9.4
Knee Flexion	16.9 $\pm$ 7.3
Lat Pull -down	37.7 $\pm$ 9.7
Knee Extension	22.7 $\pm$ 10.5
Upper Body Exercises	34.1 $\pm$ 7.4
Lower Body Exercises	33.8 $\pm$ 11.2
All Exercises	33.6 $\pm$ 7.5

#### 3.7.2 Low Velocity 1-Repetition Maximum Values

Data listed as Means  $\pm$  Standard Deviation

All values are in kilograms

Hack Squat	81.2 $\pm$ 24.4
Bench Press	46.8 $\pm$ 8.6
Knee Flexion	23.7 $\pm$ 7.9
Lat Pull -down	49.4 $\pm$ 11.5
Knee Extension	29.9 $\pm$ 6.9
Upper Body Exercises	48.0 $\pm$ 9.6
Lower Body Exercises	44.9 $\pm$ 9.1
All Exercises	47.2 $\pm$ 7.6



## **Chapter 4**

### **Discussion**

#### **4.1 Main Finding**

The main finding of this investigation was that high velocity resistance training appears to result in either more favourable or similar cardiovascular responses than low velocity resistance training. SBP, MAP, and RPE were found to be significantly lower after the high velocity resistance training than the low velocity session ( $p < 0.05$ ). HR, DBP, and RPP were not significantly different between the high and low velocity resistance training sessions, which suggests that the high velocity resistance training session may be as safe as low velocity resistance training. However, the results for HR, DBP, and RPP were all underpowered ( $< 0.80$ ), most likely due to low participant number. There have been no known reports of research studies to date that have examined the effect of contraction velocity during isotonic resistance exercise on cardiovascular and perceived responses in CHF.

#### **4.2.1 Systolic Blood Pressure and Mean Arterial Pressure**

SBP and MAP were significantly less during the high velocity resistance training session than during the low velocity resistance training session. The exercising muscle was contracted for 2 seconds longer per concentric contraction and this could be one of the reasons the low velocity elicited greater SBP and MAP responses. The other reason could have been due to the use of a higher load in the low velocity session but the response may have been washed out because of the similar power outputs. Gaskell first examined blood flow in response to the contraction of a muscle using dogs in 1877<sup>72</sup>. He observed that during a contraction, the muscle's blood vessels dilate which are opposed by the mechanical compression of the contracting muscle fibres<sup>72</sup>. If the intensity of a static contraction is great enough, the intramuscular compression

can impede the blood flow to the muscle<sup>73</sup>. The mechanical compression that occurs during muscle contractions impedes local blood flow when isometric voluntary contraction is greater than 40-60% of maximal voluntary contraction and in our study the high velocity load was 73% of the low velocity load<sup>65,66</sup>. The compression of the blood vessels causes an increase in total peripheral resistance which in turns increases SBP<sup>61</sup>.

It is difficult to compare this investigation to Degache et al.'s study examining the effect of speed of contraction on central hemodynamics in CHF because they used a different number repetitions, intensity, and mode (isokinetic dynamometer)<sup>47</sup>. In their study they only performed 3 maximal repetitions. They found a tendency that the highest SBP recorded was during the fastest velocity (60 vs. 180°/s) but this was not a statistically significant finding. They did not examine MAP. In healthy adults, the studies that have been performed are difficult to compare to our investigation. Okamoto et al., compared high and low velocity contractions using the biceps curl exercise<sup>67</sup>. They found that the high velocity session produced a significantly higher SBP and MAP than the low velocity session. This finding can be attributed to the large difference in load between the two exercise sessions. Okamoto et al. used 80% of 1-RM for the high velocity session and only 40% of 1-RM for the low velocity session<sup>67</sup>. I used 50% of 1-RM for the low velocity and 35.7% of 1-RM for the high velocity. The greater load at a higher velocity would require greater muscle mass to be utilized and result in the higher SBP and MAP. Wickwire et al. utilized a protocol comparing a 2 second concentric-4 second eccentric per rep to a super slow 10 second concentric-5 second eccentric per repetition<sup>74</sup>. They found no significant difference in SBP and did not examine MAP between the two exercise sessions. Their high velocity was also at a higher load than the low velocity, 65 vs. 40% of 1-RM respectively. Douris used an isokinetic dynamometer to compare 30, 120, and 300°/s knee flexion and extension performed

maximally for one minute<sup>58</sup>. He found no significant differences in SBP. There are a few flaws in his study protocol. First performing maximal effort exercise for 1 minute while doing both knee flexion and extension are going to produce high SBP with a constant increase no matter the velocity. By performing both flexion and extension at the same time, their exercise set more closely resembled an aerobic exercise session and would make it more difficult to detect differences between the two velocities. Douris also did not control for the number of repetitions<sup>58</sup>. The higher velocity performed more repetitions than the lower velocity sets.

#### **4.2.2 Rating of Perceived Exertion**

RPE was significantly less during the high velocity resistance training session than the low velocity resistance training session. The patients with CHF in the study therefore perceived the high velocity resistance training session to be easier than the low velocity session. This may be important because if long term high velocity training can at least result in similar physiological or functional benefits for CHF patients than slow velocity training, the high velocity training would be considered to be more efficient. There are currently no resistance training studies that have used RPE to compare any type of resistance training protocols in patients with CHF. In healthy adults, Singh et al. compared the RPE response to three different resistance training protocols: A power protocol consisting of 3 sets of 5 repetitions at 50% of 1-RM at a fast lifting speed; a strength protocol consisting of 3 sets of 5 repetitions at 90% of 1-RM; and a hypertrophy protocol consisting of 3 sets of 10 repetitions at 70% of 1-RM<sup>75</sup>. The strength and hypertrophy produced significantly greater RPE values than the power protocol. This study is difficult to compare to our investigation because they did not attempt to match the power output between the power protocol and the other two protocols. The hypertrophy protocol also had more repetitions than the power protocol which makes things even less clear but their

results are similar to what we found. Wickwire et al. found that their super slow protocol (10 second concentric-5 second eccentric) with a lower load (40% of 1-RM) produced a significantly lower RPE than performing a traditional machine protocol (2 seconds concentric-4 seconds eccentric) with a higher load (65% of 1-RM)<sup>74</sup>. This makes the low velocity session easier to perform by using a lower load than the high velocity session. The high velocity session should have a lower load than the low velocity session in an attempt to match the overall intensity. Row et al. compared the RPE from nine different loads where the repetition was performed as fast as the participant was able to. RPE ratings were found to significantly predict loads relative to % of 1-RM<sup>76</sup>.

#### **4.2.3 Rate Pressure Product**

RPP was not significantly different between the high velocity and low velocity resistance training sessions. There was a non-significant trend for RPP to be lower during the high velocity session during the upper body exercises ( $p=0.063$ ) and combined upper and lower body exercises ( $p=0.106$ ). We may have lacked statistical power for this measurement. RPP has not been used to compare different resistance training protocols in CHF. In healthy adults, a 300°/s protocol elicited a significantly higher RPP than 120 and 60°/s protocols<sup>58</sup>. RPP was also significantly greater in a high velocity protocol using 80% of 1-RM compared to a low velocity protocol that used 40% of 1-RM<sup>67</sup>. Both studies used greater loads and Douris' also used more repetitions for their high velocity protocols which would elicit greater myocardial oxygen consumption and in turn, RPP<sup>58</sup>. A significant result may have been washed out in our investigation because we did not find significant differences in HR between the two resistance training sessions even though SBP was significantly greater during the low velocity as compared to the high velocity.

#### 4.2.4 Heart Rate

HR was not significantly different between the high velocity and low velocity resistance training sessions. This result is similar to what Degache et al. found during their CHF isokinetic study<sup>47</sup>. They found no significant difference for HR between the 60 and 180°/s sessions. This contradicts what has been found in the healthy population. In the study by Okamoto et al., the high velocity session was found to have a significantly higher HR than the low velocity session<sup>67</sup>. In the study by Wickwire et al., the traditional machine resistance protocol produced a significantly higher HR than the super slow protocol<sup>74</sup>. Douris found that HR was significantly greater during the 300°/s session as compared to the 30°/s<sup>58</sup>. All of the studies with healthy populations show that the HR is highest during the resistance exercise session that uses the highest power (highest load combined with the highest velocity of contraction). The reason that we do not see any differences in the CHF population may be due to the medications that the CHF population are on. Adrenergic  $\beta$ -antagonist ( $\beta$ -blocker) therapy is very common in patients with CHF, 3 out of 7 prescribed  $\beta$ -blockers and the other 4 out of 7 were prescribed combined  $\alpha$ - &  $\beta$ -blockers.  $\beta$ -blockers are prescribed to increase coronary perfusion by prolonging diastole through a decrease in HR and myocardial contractility<sup>77</sup>. In response to a set of resistance exercise adults taking  $\beta$ -blockers had a significantly lower HR than adults who were not taking  $\beta$ -blockers<sup>78</sup>.  $\beta$ -blockers blunt the HR response to resistance exercise and this may be the reason why there were no significant differences between the high velocity resistance training session and the low velocity resistance training session.  $\beta$ -blockers are also known to decrease blood pressure directly and indirectly; directly,  $\beta$ -blockers inhibit  $\beta_2$ -adrenoreceptors located in vascular musculature responsible for vasoconstriction; and indirectly, the decrease in HR causes a decrease in blood pressure<sup>79</sup>.

#### 4.2.5 Diastolic Blood Pressure

DBP was not significantly different between the high velocity and low velocity resistance training sessions. DBP has not been used to compare different velocities of contraction in patients with CHF. In healthy adults, DBP was examined in the studies by Okamoto et al. and Douris to compare different velocities of contraction<sup>67,58</sup>. Okamoto et al. found that DBP was significantly greater in response to the high velocity resistance exercise as compared to the low velocity resistance exercise<sup>67</sup>. In the study by Douris, no significant differences were found in DBP between the different isokinetic velocities<sup>58</sup>. The higher intensity resistance exercise should elicit a significantly higher DBP than the lower intensity due to the exercise pressor reflex where vasodilation occurs at the exercising muscle and vasoconstriction occurs in the non-exercising areas of the body. This may not have occurred in our study and in Douris's study because of the use of medications that have a vasodilatory effect or prevent vasoconstriction in patients with CHF. These drugs are used for the treatment of hypertension. They include  $\alpha$ -adrenoceptor antagonists ( $\alpha$ -blockers), angiotensin converting enzyme (ACE) inhibitors, angiotensin II receptor antagonists also known as angiotensin receptor blockers (ARB), and calcium channel blockers.  $\alpha$ -blockers work by blocking  $\alpha_1$ -adrenergic receptors, which are responsible for vasoconstriction<sup>79,80</sup>. Blocking  $\alpha_1$ -adrenergic receptors can prevent vasoconstriction from occurring. ACE inhibitors act mainly to decrease activation of the rennin-angiotensin-aldosterone system by preventing inactive angiotensin I from being converted to angiotensin II, the most vasoactive product of the renin-angiotensin-aldosterone system<sup>79</sup>. Angiotensin II produces vasoconstriction and a retention of sodium and water; inhibition of angiotensin II decreases vasoconstriction and sodium and water<sup>80</sup>. ARBs work in a similar manner as ACE inhibitors. ARBs work to prevent angiotensin II from binding to the angiotensin type one receptor. ARBs

block the angiotensin type one receptor, decreasing vasoconstriction<sup>79</sup>. Calcium channel blockers work on the voltage-gated calcium channels of the plasma membrane. They block the transmembrane influx of calcium through the slow channel into the vascular smooth muscle causing a reduction of free calcium ions in the muscle tissue. This leads to a depression of mechanical contraction of smooth muscle and depression of both impulse formation and conduction velocity<sup>79</sup>. This causes a relaxation of the vascular smooth muscle cells and leads to vasodilation. The exercise pressor reflex can be blunted by  $\alpha$ -blockers, ACE inhibitors and ARBs preventing vasoconstriction or by calcium channel blockers that negate vasoconstriction in the non-exercising areas of the body through vasodilation and therefore prevent the increase in DBP<sup>77</sup>. By blunting the DBP response, it makes it difficult to see significant differences between the two exercise sessions.

### **4.3 Limitations**

There are a few limitations to the current investigation. One obvious limitation is the low participant number. A low participant number means that we cannot draw any definite conclusions. This is a pilot study examining a novel training protocol in patients with CHF. This is the first study to compare the cardiovascular effects of different velocities of contraction in patients with CHF.

Another limitation of this study was that it was not blinded. The primary investigator measured SBP and DBP during both the high and low velocity resistance training sessions. An ideal design would have been to have had an independent practitioner who measured blood pressure and was unaware of the study design. This limitation was reduced by using standardized procedures.

Another limitation of this study was that the researcher did not request that the participants control their diet prior to the exercise sessions. An ideal design would have had the participants eating a similar diet before partaking in the exercise testing sessions.

#### **4.4 Practical Implications and Future Research**

Low velocity resistance training has been determined to be safe in patients with CHF. The results of this study suggest that it may also be safe for patients with CHF to utilize a high velocity to perform their resistance training exercises. Future studies could examine the effect of the high velocity training on the heart by using an echocardiogram to detect wall motion abnormalities and other abnormalities that may occur. Future studies should examine the effectiveness of using high velocity resistance training to improve quality of life and functional activities in patients with CHF.

This investigation has been the first to compare different concentric resistance training velocities that attempted to match power output. The novel method used for determining the high velocity load will allow researchers to more accurately compare different resistance training velocities while controlling for power output in a non-clinical setting.



## **Chapter 5**

### **Conclusions**

The purpose of this study was to compare the differences between a high velocity resistance training session and a low velocity resistance training session on central hemodynamics and perceived exertion. This was the first study that used a similar relative intensity for both a high and a low velocity resistance training session. SBP, MAP, and RPE were all found to be significantly greater during the low velocity session compared to the high velocity session. These results support part of our hypotheses and suggest that high velocity resistance training places a smaller training load on the heart of patients with CHF than low velocity resistance training. Patients with CHF also perceive that the high velocity session is easier to perform than the low velocity session. Contrary to the hypotheses, RPP, DBP, and HR were not significantly different between the low and high velocity session. Medications that patients with CHF are managed with may affect these results. No adverse events occurred during this study which, if replicated in a study using a greater sample size, would add to the safety of resistance training in patients with CHF and may support the rationale for high velocity resistance training.

## References

- <sup>1</sup>Heart and Stroke Foundation of Saskatchewan. (2008). Retrieved: November 24, 2008.  
Statistics. Available from:  
<http://www.heartandstroke.sk.ca/site/c.inKMILNIEmG/b.3657463/#chf>
- <sup>2</sup>Arnold J, Liu P, Demers C, et al. Canadian Cardiovascular Society consensus conference recommendations on heart failure 2006: Diagnosis and management. *Can J Cardiol.* 2006;22(1) 23-45.
- <sup>3</sup>Meyer K. Resistance exercise in chronic heart failure – Landmark studies and implications for practice. *Clin Invest Med*,2006;3:166-169.
- <sup>4</sup>Miszko T, Cress M, Slade J, et al. Effect of strength and power training on physical function in community-dwelling older adults. *The Journals of Gerontology.* 2003;58(2):171 – 175.
- <sup>5</sup>Bottaro M., Machado S., Nogueira, et al. Effect of high versus low-velocity resistance training on muscular fitness and functional performance in older men. *European Journal of Applied Physiology.* 2007;99:257-264.
- <sup>6</sup>Myers JN & Brubaker PH. Chronic heart failure. In: Durstine JL, Moore GE, Painter PL, Roberts SO, editors. ACSM's Exercise management for persons with chronic diseases and disabilities. 3<sup>rd</sup> Ed. Champaign: Human Kinetics.
- <sup>7</sup>Keteyian SJ, Brawner CA, Schaierer JR. Exercise Testing and training of patients with heart failure due to left ventricular systolic dysfunction. *J Cardiopulm Rehabil.* 1997;17:19-28.
- <sup>8</sup>Volaklis, K. & Tokmakidis, S. (2005) Resistance exercise training in patients with heart failure. *Sports Med.* 2005;35(12):1085 – 1103.
- <sup>9</sup>McKelvie RS, Benedict CR, & Yusuf S. Evidence based cardiology: prevention of congestive

- heart failure and management of asymptomatic left ventricular dysfunction. *BMJ*. 1999  
318(7195):1400-2
- <sup>10</sup> Meyer K, Hajric R, Westbrook S, et al. Hemodynamic responses during leg press exercise in patients with chronic congestive heart failure. *Am J Cardiol*. 1999;83:1537-1543.
- <sup>11</sup> Cheetham, C., Green, D., Collis, et al. Effect of aerobic and resistance exercise on central hemodynamic responses in severe chronic heart failure. *J Appl Physiol*. 2002;93:175-180.
- <sup>12</sup> Karlsdottir A, Foster C, Porcari J, et al. Hemodynamic responses during aerobic and resistance exercise. *Journal of Cardiopulmonary Rehabilitation*. 2002;22:170-177.
- <sup>13</sup> Werber-Zion G, Goldhammer E, Shaar A, et al. *Journal of Cardiopulmonary Rehabilitation*. 2004;24: 100-109.
- <sup>14</sup> Meyer T, & Tighe D. *Dx/Rx: Heart Failure*. Sudbury, MA: Jones and Bartlett Publishers; 2005.
- <sup>15</sup> Delagardelle C, Feiereisen P, Krecke R, et al. Objective effects of a 6 months' endurance and strength training program in outpatients with congestive heart failure. *Med Sci Sports Exerc*. 1999;31(8):1102-1107.
- <sup>16</sup> Levinger I, Bronks R, Cody D, et al. The effect of resistance training on left ventricular function and structure of patients with chronic heart failure. *I J Card*. 2005;105:159-163.
- <sup>17</sup> Mandic S, Tymchak W, Kim D, et al. Effects of aerobic or aerobic and resistance training on cardiorespiratory and skeletal muscle function in heart failure: a randomized controlled pilot trial. *Clinical Rehabilitation*. 2009;23:207-216.
- <sup>18</sup> Conraads, V., Beckers, P., Vaes, J., et al. Combined endurance/resistance training reduces NT-proBNP levels in patients with chronic heart failure. *Eur Heart J*. 2004;25:1797-1805.
- <sup>19</sup> Feiereisen P, Delagardelle C, Vaillant M, et al. Is strength training the more efficient training

- modality in chronic heart failure? *Med Sci Sports Exerc*, 2007;11:1910-1916.
- <sup>20</sup> Beckers P, Denollet J, Possemiers N, et al. Combined endurance-resistance training vs. endurance training in patients with chronic heart failure: a prospective randomized study. *Eur Heart J*. 2008;29:1858-1866.
- <sup>21</sup> Delagardelle C, Feiereisen P, Autier P, et al. Strength/endurance training versus endurance training in congestive heart failure. *Med Sci Sports Exerc*. 2002;34:1868-1872.
- <sup>22</sup> Conraads V, Beckers P, Bosmans J, et al. Combined endurance/resistance training reduces plasma TNF- receptor levels in patients with chronic heart failure and coronary artery disease. *Eur Heart J*. 2002;23:1854-1860.
- <sup>23</sup> Tsutamoto T, Wada A, Maeda K, et al. Attenuation of compensation of endogenous cardiac natriuretic peptide system in chronic heart failure: prognostic role of plasma brain natriuretic peptide concentration in patients with chronic symptomatic left ventricular dysfunction. *Circulation*. 1997;96: 509-516.
- <sup>24</sup> Cheng V, Kazanagra R, Garcia A, et al. A rapid bedside test for B-type peptide predicts treatment outcomes in patients admitted for decompensated heart failure: a pilot study. *J Am Coll Cardiol*. 2001;37: 386-391.
- <sup>25</sup> Koglin J, Pehlivanli S, Schwaiblmair, M, et al. Role of brain natriuretic peptide in risk stratification of patients with congestive heart failure. *J Am Coll Cardiol*. 2001;38:1934-1941.
- <sup>26</sup> Selig S, Carey M, Menzies D, et al. Moderate-intensity resistance exercise training in patients with chronic heart failure improves strength, endurance, heart rate variability, and forearm blood flow. *J Cardiac Failure*. 2004;10(1): 21-30.
- <sup>27</sup> Williams, A., Carey, M., Selig, S., et al. Circuit Resistance Training in Chronic Heart Failure

- Improves Skeletal Muscle Mitochondrial ATP Production Rate - A Randomized Controlled Trial. *J of Cardiac Fail.* 2007;13(2):79-85.
- <sup>28</sup> Degache F, Garet M, Calmels P, et al. Enhancement of isokinetic muscle strength with a combined training programme in chronic heart failure. *Clinical Physiology and Functional Imaging*, 2007;27(4):225-230.
- <sup>29</sup> Hare D, Ryan T, Selig S, et al. Resistance exercise training increases muscle strength, endurance, and blood flow in patients with chronic heart failure. *The American Journal of Cardiology*. 1999;83:1674-1677.
- <sup>30</sup> Pu C, Johnson M, Forman D, et al. Randomized trial of progressive resistance training to counteract the myopathy of chronic disease. *J Appl Physiol*. 2001;90:2341-2350.
- <sup>31</sup> Maiorana A, O'Driscoll G, Cheetham C, et al. Combined aerobic and resistance exercise training improves functional capacity and strength in CHF. *J Appl Physiol*. 2000;88:1565-1570.
- <sup>32</sup> Levinger I, Bronks R, Cody D, et al. Resistance training for chronic heart failure patients on beta blocker medications. *I J Card*. 2005;102:493-499.
- <sup>33</sup> Keteyian SJ. Exercise rehabilitation in chronic heart failure. *Coron Artery Dis*. 2006;17:233-237.
- <sup>34</sup> Paterson DH, Cunningham DA, Koval JJ, et al. Aerobic fitness in a population of independently living men and women aged 55-86 years. *Med Sci Sports Exerc*. 1999;(12):1813-20.
- <sup>35</sup> Maiorana, A., O'Driscoll, G., Dembo, L., et al. Effect of aerobic and resistance exercise training on vascular function in heart failure. *Am J Physiol Heart Circ Physiol*. 2005;279:

H1999-H2005.

- <sup>36</sup> Magnusson G, Gordon A, Kaljert L, et al. High intensity knee extensor training, in patients with chronic heart failure. *Eur Heart J*. 1996;17:1048-1055.
- <sup>37</sup> Hambrecht R, Gielen S, Linke A et al. Effects of exercise training on left ventricular function and peripheral resistance in patients with chronic heart failure. *JAMA*. 2000;283:3095-3101.
- <sup>38</sup> Roveda F, Middlekauff HR, Urbanaet M, et al. The effects of exercise training on sympathetic neural activation in advanced heart failure. *J Am Coll Cardiol*. 2003;42:854-860.
- <sup>39</sup> Kaye, D., Lefkovits, J., Jennings G., et al. Adverse consequences of high sympathetic nervous activity in the failing human heart. *J Am Coll Cardiol*. 1995;26:1257-1263.
- <sup>40</sup> Kiilavuori K, Toivonen L, Naveri H, et al. Reversal of autonomic derangements by physical training in chronic heart failure assessed by heart rate variability. *Eur Heart J*. 1995;16:490-495.
- <sup>41</sup> Nolan J, Batin PD, Andrews R et al. Prospective study of heart rate variability and mortality in chronic heart failure. *Circulation*. 1998;98:1510-1516.
- <sup>42</sup> Iravanian S, Arshad A, & Steinberg JS. Role of electrophysiologic studies, signal-averaged electrocardiography, heart rate variability, T-wave alternans, and loop recorders for risk stratification of ventricular arrhythmias. *Am J Geriatr Cardiol*. 2005;14(1):16-9
- <sup>43</sup> Fei L, Keeling PJ, Sadoul N, et al. Decreased heart rate variability in patients with congestive heart failure and chronotropic incompetence. *PACE*. 1996;19:477-483.
- <sup>44</sup> Keteyian SJ, Brawner CA, Schairer JR, et al. Effects of exercise training on chronotropic incompetence in patients with heart failure. *Am Heart J*. 1999;138:233-240.
- <sup>45</sup> Nelson RR, Gobel FL, Jorgensen CR, et al. Hemodynamic predictors of myocardial oxygen

- consumption during static and dynamic exercise. *Circulation*. 1974;50:1174-1189.
- <sup>46</sup>Kitamura K, Jorgensen CR, Jorgensen FL, et al. Hemodynamic correlates of myocardial oxygen consumption during upright exercise. *J Appl Physiol*. 1972;32:516-522
- <sup>47</sup> Degache, F., Roche, F., Bernard, P., et al. Cardiovascular responses during isokinetic knee extension testing in chronic heart failure patients. *Isokinetics and Exercise Sciences*. 2009;17:63-67.
- <sup>48</sup> Fielding R, LeBrasseur N, Cuoco A, et al. High-velocity resistance training increases skeletal muscle peak power in older women. *Journal of American Geriatrics Society* 2002;50:655-662.
- <sup>49</sup> Hazell T, Kenno K, & Jakobi J. Functional benefit of power training for older adults. *J Aging and Phys Act*. 2007;15:349-359.
- <sup>50</sup> Sayers S, Bean J, Cuoco A, et al. Changes in function and disability after resistance training: does velocity matter? *American Journal of Physical Medicine & Rehabilitation*. 2003;82(8):605-613.
- <sup>51</sup> Henwood T, Rick S, & Taaffe D. Strength versus muscle power-specific resistance training in community-dwelling older adults. *Journal of Gerontology*. 2009;63A:83-91.
- <sup>52</sup> McKelvie R, McCartney N, Tomlinson C, et al. Comparison of hemodynamic responses to cycling and resistance exercise in congestive heart failure secondary to ischemic cardiomyopathy. *The American Journal of Cardiology*. 1995;76:977-979.
- <sup>53</sup> Lentini AC, McKelvie RS, McCartney N, et al. Left ventricular response in healthy young men during heavy-intensity weight-lifting exercise. *J Appl Physiol*. 1993;75(6):2703-2710.
- <sup>54</sup> Miles DS, Owens JJ, Golden JC, et al. Central and peripheral hemodynamics during maximal leg extension exercise. *Eur J Appl Physiol*. 1987;56:12-17.

- <sup>55</sup>Sale DG, Moroz DE, McKelvie RS, et al. Comparison of blood pressure response to isokinetic and weight-lifting exercise. *Eur J App Physiol*. 1993;67:115-120.
- <sup>56</sup>MacDougall JD, Tuxen D, Sale DG, et al. Arterial blood pressure response to heavy resistance exercise. *J Appl Physiol*. 1975;58(3):785-790.
- <sup>57</sup>Fleck SJ & Dean LS. Resistance-training experience and the pressor response during resistance exercise. *J Appl Physiol*. 1987;63(1):116-120.
- <sup>58</sup>Douris PC. Cardiovascular responses to velocity-specific isokinetic exercise. *JOSPT*. 1991;13(1):28-32.
- <sup>59</sup>Castinheras-Neto AG, Rodrigues da Costa-Filho I, & Veras Farinatti PT. Cardiovascular responses to resistance exercise are affected by workload and intervals between sets. *Arq Bras Cardiol*. 2010; 95(4):493-501.
- <sup>60</sup>Stralow CR, Ball TE, & Looney M. Acute cardiovascular responses of patients with coronary disease to dynamic variable resistance exercise of different intensities. *J Cardiopulmonary Rehabil*. 1993;13:255-263.
- <sup>61</sup>MacDougall JD, McKelvie RS, Moroz DE, et al. Factors affecting blood pressure during heavy weight lifting and static contractions. *J Appl Physiol*. 1985;73(4):1590-1597.
- <sup>62</sup>Murphy MN, Mizuno M, Mitchell JH et al. Cardiovascular regulation by skeletal muscle reflexes in health and disease. *Am J Physiol Heart Circ Physiol*. 2011;301:H1191-H1204.
- <sup>63</sup>Gary MG. Abnormalities of the exercise pressor reflex in heart failure. *Exerc. Sport Sci. Rev*. 2011;39(4):167-176.
- <sup>64</sup>Fleck SJ. Cardiovascular adaptations to resistance training. *Med Sci Sports Exerc*. 1988;20(5):S146-S151.
- <sup>65</sup>Bonde-Peterson F, Mork AL, & Nielsen E. Local muscle blood flow and sustained contractions



- of human arms and back muscles. *Eur J Appl Occup Physiol*. 1975;34:43-50.
- <sup>66</sup>Hall-Jurkowski JJ, Sutton R, & Duke RJ. Subarachnoid hemorrhage in association with weightlifting (Abstract). *Can J Appl Sports Sci*. 1983;8:210
- <sup>67</sup>Okamoto T, Masuhara M, & Ikuta K. Low intensity resistance exercise with slow lifting and lowering does not increase noradrenalin and cardiovascular responses. *Clin Physiol Funct Imaging*. 2009;29:32-37.
- <sup>68</sup>Heo S, Moser D, Lennie T, et al. A comparison of health-related quality of life between older adults with heart failure and healthy older adults. *Heart & Lung*. 2007;January/February:16-24.
- <sup>69</sup>Rector TS. Overview of the Minnesota living with heart failure questionnaire. 2005.
- <sup>70</sup>Wiecek E, McCartney N, & McKelvie R. Comparison of direct and indirect measures of systemic arterial pressure during weightlifting in coronary artery disease. *Am J Cardiol*. 1990;66:1065-1069.
- <sup>71</sup>King M, Dracup K, & Woo M. Predictors of isotonic exercise in patients with heart failure. *Med Sci Sports Exerc*. 2001;33(7):1090-1095.
- <sup>72</sup>Gaskell WH. The changes of the blood-stream in muscles through stimulation of their nerves. *J Anat Physiol*, 1877;11(Pt.3):360-402.3.
- <sup>73</sup>Lind AR & McNicol GW. Muscular factors which determine the cardiovascular responses to sustained and rhythmic exercise. *Canad Med Ass J*. 1967;96:706-713.
- <sup>74</sup>Wickwire PJ, McLester JR, Green JM, et al. Acute heart rate, blood pressure, and RPE responses during super slow vs. traditional machine resistance training protocols using small muscle group exercises. *J Strength Cond Res*. 2009;23(1):72-79.
- <sup>75</sup>Singh F, Foster C, Tod D, et al. Monitoring different types of resistance training using session

- rating of perceived exertion. *IJSPP*. 2007;2:34-45.
- <sup>76</sup>Row BS, Knutzen KM, & Skogsberg NJ. Regulating explosive resistance training intensity using the rating of perceived exertion. *J Strength Cond Res*. 2012;26(3):664-671.
- <sup>77</sup>Orbach P & Lowenthal DT. Evaluation and treatment of hypertension in active individuals. *Med Sci Sports Exerc*. 1988;30(10Suppl):S354-S366.
- <sup>78</sup>Miguel FM, Grings LA, Pereira GB, et al. Different cardiovascular responses to a resistance training session in hypertensive women receiving propranolol compared with normotensive controls. *TheScientificWorldJournal*. 2012;913271.
- <sup>79</sup>Canadian Pharmacists Association. *Compendium of Pharmaceuticals and Specialties 2011*. Ottawa: Canadian Pharmacists Association; 2011.
- <sup>80</sup>Abrams AC. *Clinical Drug Therapy Rationales for Nursing Practice*. 7<sup>th</sup> Ed. Philadelphia: Lippincott Williams & Wilkins; 2004.

## **Appendix A: Consent Form**

### **Research Participant Information and Consent Form**

**TITLE:** High versus low velocity resistance training in chronic heart failure patients.

**PRINCIPAL INVESTIGATOR:** Dr. Philip Chilibeck, Ph.D. College of Kinesiology,  
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**SUB-INVESTIGATORS:** Dr. Scott Butcher, Ph.D. School of Physical Therapy,  
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**EMERGENCY PHONE NUMBER:** (306) 230-3849

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#### **INTRODUCTION**

You are invited to take part in this research study because you have chronic heart failure. Your participation is entirely voluntary, so it is up to you to decide whether or not you wish to take part. We are seeking 45 chronic heart failure patients to complete this study. You will not lose the benefit of any medical care to which you are entitled or are presently receiving or lose access to any of the recreational facilities. If you decide to take part in this study, you are still free to withdraw at any time and without giving any reasons for your decision.

This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand. You may ask as many questions as you need to understand what the study involves. Please feel free to discuss this with your family, friends or family physician.

#### **STUDY PURPOSE:**

Recent information indicates that resistance training should be part of a rehabilitation program for patients with chronic heart failure. The current guidelines do not describe the speed at which resistance training should be done at. The purpose of this study is to compare resistance training protocols of high velocity, or fast speed, versus low velocity, or slow speed, to identify optimum training protocols for patients with chronic heart failure. We hope that the results of this study can be applied to exercise programs for patients with chronic heart failure.

**STUDY DESIGN:**

There will be three study groups. One will participate in high velocity, or fast speed, resistance training (i.e. strength training), another will participate in low velocity, slow speed, resistance training and the other group will not participate in the resistance training and will continue with the usual care and programming that you receive. You will be randomly assigned (i.e. assigned by chance by a computer) to one of these three groups. You will have an equal chance of getting into either group. In addition to the time you spend exercising in the cardiac rehabilitation program, you will be required to attend 3 exercise sessions per week for 3 months if you are randomized into one of the resistance training groups. Exercise sessions will last 40 minutes each. You will be required to attend eight testing sessions as well.

**STUDY PROCEDURES:**

The study staff will carefully explain all procedures and you should ask whenever you need more information. You must provide consent to participate in this study before you perform any study-related procedures.

As a participant in this study, you will be asked to complete the following procedures:

Testing Session #1: If you are willing to take part in the study, you will be asked to attend a screening visit, which will last about 1.5 hours. This will occur approximately two weeks prior to the start of your exercise session. At this visit a certified exercise professional will check whether you are suitable for the study: You will be asked some questions about your medical history and the medications you are using; and you will have a general health check up which will include blood pressure measurements.

You will be asked to perform some functional tests by the same certified exercise professional. These will be timed tests. The first will require you to start from a seated position in a chair, walk eight feet, and return to the chair. The second test will require you to start from a seated position again and you will have to stand up from the chair as many times as you can within 30-seconds. The third test will time you on how fast you can climb a flight of stairs. The last test will have you walk as far as you can around the track for 6-minutes.

After completing these tests you will then be familiarized with the resistance training equipment by the certified exercise professional. This will include being taught how to use the equipment and proper technique. At the end of this session you will then be booked in for an echocardiogram if you have not had one in the past 6 months.

Testing Session #2: This testing session will depend on whether you have had an echocardiogram within the past 6 months or not. This session will take place at Dr. Akhtar's office and will take approximately 1 hour.

Testing Session #3: During this testing session you will be doing strength testing with the same exercise professional. For each exercise you will be tested for your 1-repetition maximum, or how much weight you can lift for one repetition. This session will last approximately 45 minutes. This will occur approximately one week prior to the start of the study. Strength testing

will occur every 2 weeks during a training session. During the strength testing a medical doctor will be present and cardiovascular monitoring will occur as well. The cardiovascular monitoring we will be using is telemetry and we will use it to monitor your electrocardiograph or the rhythm of your heart and your heart rate.

Testing Session #4 & #5: On these days of testing you will perform the workout. One day you will do it at the fast speed and the other day at the slower speed. Heart rate, blood pressure and a rating of perceived exertion will be recorded after every set of every exercise.

The first 3 testing sessions will be repeated at the end of the study.

Training Sessions: Training sessions will start with a 5-minute warm-up. The warm-up will be followed by 40 minutes of resistance training. The resistance training will consist of 5 different exercises. For each exercise you will start with 1 sets of 12 repetitions and progress to more on an individualized basis, based on your performance during strength testing. The high velocity training will consist of a 1 second lifting phase and a 3 second lowering phase. The low velocity group will consist of a 3 second lifting phase and a 3 second lowering phase. You will then participate in your normal endurance training that you do at the Field House, followed by a 5-minute cool-down.

All testing and training sessions will have a physician in attendance.

### **BENEFITS:**

If you choose to participate in this study, there may be direct benefits to you such as improved quality of life, improvements in your activities of daily living, and an improvement in muscle strength. However, benefits are not guaranteed. It is hoped the information gained from this study can be used in the future to benefit other people with a similar condition.

### **RISKS AND DISCOMFORTS:**

The study doctor may decide that you should not perform the exercises or the exercise tests, based on information in your medical history. It is important that you let the study doctor or staff know if you have ever been advised not to participate in strenuous activities. It is also important that you report any pain, discomfort, fatigue or other symptoms that you might have during the exercises to the physician in attendance.

If you experience any symptoms while a participant in this study seek immediate medical attention and inform the emergency medical personnel that you are a participant in this study. You should then inform the study staff at 230-3849. As with any type of strenuous activity, there is a small risk that the stress of performing exercise will cause heart rhythm abnormalities, chest discomfort or light headedness.

Risks and discomforts will be minimized by preliminary screening and examination, by observations made throughout the study, and through close access to emergency equipment and medical personnel. You will be carefully monitored throughout testing and a physician will be immediately available in case problems should arise. All tests will be performed by staff who are

trained to deal with problems that may arise. At any time during the study, it is important that you tell the study staff if you feel unwell or experience any problems or side effects.

Due to the nature of strength testing you may experience fatigue. However, all attempts will be made to minimize this effect, including alterations to exercise programs.

In 10 studies 232 chronic heart failure patients participated in resistance training. The incidences of adverse events were low. There were only two adverse events reported. In one participant atrial fibrillation occurred and in the other sudden death at home three days after the last training session occurred. These adverse events may not have even been linked to the training programs. This rate of adverse events is similar to those reported from training programs that only included endurance training.

### **COST AND REIMBURSEMENTS**

You will not be charged for any research-related procedures. You will not be paid for participating in this study.

### **RESEARCH-RELATED INJURY:**

In the case of a medical emergency related to the study, you should seek immediate care and, as soon as possible, notify the study staff. Necessary medical treatment will be made available at no cost to you. By signing this document, you do not waive any of your legal rights.

### **CONFIDENTIALITY:**

The researchers will protect your privacy, and safeguard the confidentiality of information collected about you during the course of this study. While specific measures will be taken to maintain confidentiality, there is still a chance of unintentional release of personal information. You will be identified in this study only by an assigned study number. Access to your personal health information may include copying and taking copies away. However, in this case, all personal identifiers would first be removed and substituted by your assigned study number. Rarely, your study documents may be obtained by courts of law. Reports based on results of this study may be presented for medical and scientific publication, but your identity will not be disclosed. You have the right to check your research study records and health records and request changes if the information is not correct.

With your permission, the study staff may inform your family physician of your participation in this study. He/she may be consulted regarding your health and treatment.

### **NEW INFORMATION:**

The study staff will tell you about new information that may affect your health, welfare, or willingness to stay in this study.

When this study is complete your results and the results of the study will be made available to you upon request.

### **VOLUNTARY WITHDRAWAL FROM THE STUDY:**

If you do decide to take part in this study, you are still free to withdraw at any time and without giving reasons for your decision. There will be no penalty or loss of benefits to which you are otherwise entitled, and your future medical care or access to recreational facilities will not be affected. If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during enrolment in the study will be retained for analysis up to the point of your withdrawal.

#### **WITHDRAWAL INITIATED BY THE INVESTIGATOR**

You may be withdrawn from the study if:

- Staying in the study would be harmful.
- You need treatment not allowed in the study.
- You fail to follow instructions.

#### **CONTACT INFORMATION:**

If you have any questions about this study or your care/treatment or desire further information about this study before or during participation, you can contact Brendan Pikaluk at 374-9762 or 290-9762, or Phil Chilibeck at 343-6577 or 230-9849.

If you have any questions about your rights as a research subject or concerns about the study, you should contact the Chair of the Biomedical Research Ethics Board, c/o the Ethics Office, University of Saskatchewan, at 306-966-4053.

This study has been reviewed and approved on ethical grounds by the University of Saskatchewan Biomedical Research Ethics Board. The Research Ethics Board reviews human research studies. It protects the rights and welfare of the people taking part in those studies.

## High versus low velocity resistance training in chronic heart failure patients

### CONSENT TO PARTICIPATE

I have read (or someone has read to me) the information in this consent form.

I understand the purpose and procedures and the possible risks and benefits of the study.

I have been informed of the other treatments available for my condition.

I was given sufficient time to think about it.

I had the opportunity to ask questions and have received satisfactory answers.

I am free to withdraw from this study at any time for any reason and the decision to stop taking part will not affect my future medical care.

I agree to follow the study staff's instructions and will tell the study staff at once if I feel I have had any unexpected or unusual symptoms.

I have been informed there is no guarantee that this study will provide any benefits to me.

I give permission for the use and disclosure of my de-identified personal health information collected for the research purposes described in this form.

I understand that by signing this document I do not waive any of my legal rights.

I will be given a signed and dated copy of this consent form.

My family physician can be informed about my participation in this study, and, if required, consulted regarding my health and treatment.

- ☐ Yes, you may contact my primary care physician
- ☐ No, please do not contact my primary care physician
- ☐ I do not have a primary care physician.

*(If applicable)* I grant the Saskatchewan Ministry of Health permission to disclose my health care information to the study researchers ☐ Yes ☐ No

I agree to participate in this study:

Printed name of participant

Signature

Date

Printed name of person obtaining consent

Signature

Date



## Appendix B: 1-RM Data Collection Sheet

SUBJECT INITIALS: \_\_\_\_\_

RECRUITMENT ID #: \_\_\_\_\_

### TREATMENT: Fitness Testing

Date of measurement: \_\_\_\_\_  
(Day/month/year)

#### Vital Signs

BP: \_\_\_\_\_ (mmHg)

HR: \_\_\_\_\_ (bpm)

#### Muscular Strength

1RM hack squat: Knee Angle \_\_\_\_\_ Foot Platform \_\_\_\_\_

WARM-UP: Load \_\_\_\_\_ lbs Reps \_\_\_\_\_  
High Velocity 1RM = \_\_\_\_\_ lbs  
Low Velocity 1RM = \_\_\_\_\_ lbs

#### 1RM Bench Press: Stoppers: Up Down

WARM-UP: Load \_\_\_\_\_ lbs Reps \_\_\_\_\_  
High Velocity 1RM = \_\_\_\_\_ lbs  
Low Velocity 1RM = \_\_\_\_\_ lbs

#### 1RM Knee Flexion

WARM-UP: Load \_\_\_\_\_ lbs Reps \_\_\_\_\_  
High Velocity 1RM = \_\_\_\_\_ lbs  
Low Velocity 1RM = \_\_\_\_\_ lbs

#### 1RM Lat Pull Down

WARM-UP: Load \_\_\_\_\_ lbs Reps \_\_\_\_\_  
High Velocity 1RM = \_\_\_\_\_ lbs  
Low Velocity 1RM = \_\_\_\_\_ lbs

#### 1RM Knee Extension

WARM-UP: Load \_\_\_\_\_ lbs Reps \_\_\_\_\_  
High Velocity 1RM = \_\_\_\_\_ lbs  
Low Velocity 1RM = \_\_\_\_\_ lbs

Form Complete by: \_\_\_\_\_ Date: \_\_\_\_\_

Signature of PI: \_\_\_\_\_ Date: \_\_\_\_\_

## Appendix C: Resistance Training Session Data Sheet

SUBJECT INITIALS: \_\_\_\_\_

RECRUITMENT ID #: \_\_\_\_\_

TREATMENT: \_\_\_\_\_ Velocity Workout

Date of measurement: \_\_\_\_\_  
(Day/month/year)

### Vital Signs

BP: \_\_\_\_\_ (mmHg)  
HR: \_\_\_\_\_ (bpm)

**Hack squat: Knee Angle** \_\_\_\_\_ **Foot Platform** \_\_\_\_\_

Load \_\_\_\_\_ lbs      Reps \_\_\_\_\_  
Blood Pressure = \_\_\_\_\_ mmHg  
Heart Rate = \_\_\_\_\_ bpm  
RPE = \_\_\_\_\_

**Bench Press: Stoppers: Up      Down**

Load \_\_\_\_\_ lbs      Reps \_\_\_\_\_  
Blood Pressure = \_\_\_\_\_ mmHg  
Heart Rate = \_\_\_\_\_ bpm  
RPE = \_\_\_\_\_

### Knee Flexion

Load \_\_\_\_\_ lbs      Reps \_\_\_\_\_  
Blood Pressure = \_\_\_\_\_ mmHg  
Heart Rate = \_\_\_\_\_ bpm  
RPE = \_\_\_\_\_

### Lat Pull Down

Load \_\_\_\_\_ lbs      Reps \_\_\_\_\_  
Blood Pressure = \_\_\_\_\_ mmHg  
Heart Rate = \_\_\_\_\_ bpm  
RPE = \_\_\_\_\_

### Knee Extension

Load \_\_\_\_\_ lbs      Reps \_\_\_\_\_  
Blood Pressure = \_\_\_\_\_ mmHg  
Heart Rate = \_\_\_\_\_ bpm  
RPE = \_\_\_\_\_

Form Complete by: \_\_\_\_\_ Date: \_\_\_\_\_

Signature of PI: \_\_\_\_\_ Date: \_\_\_\_\_

## **Appendix D: Rating of Perceived Exertion Scale**

0	NOTHING AT ALL
0.5	VERY, VERY LIGHT
1	VERY LIGHT
2	FAIRLY LIGHT
3	MODERATE
4	SOMEWHAT HARD
5	HARD
6	
7	VERY HARD
8	
9	
10	VERY VERY HARD (MAXIMAL)